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SUMMARY OF RESEARCH

NUTRITION RESEARCH UNIT

1985 - 1986



ROMAN L. HRUSKA US MEAT ANIMAL RESEARCH CENTER  
P. O. BOX 166, CLAY CENTER, NEBRASKA 68933  
U S DEPARTMENT OF AGRICULTURE  
AGRICULTURAL RESEARCH SERVICE

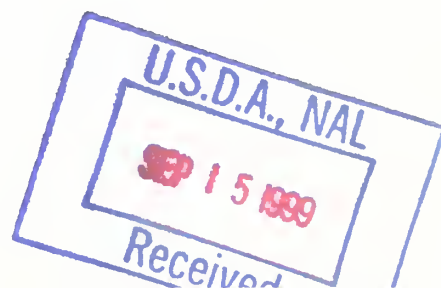


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Upper Left .....	Cow Calf Nutrition
Upper Right .....	Swine Metabolism Studies
Center .....	Aerial View of the Roman L. Hruska U.S. Meat Animal Research Center
Lower Right.....	Ewe and Lamb Nutrition
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## Goals of the Nutrition Research Unit

The goals of the Nutrition Research Unit of the Roman L. Hruska U.S. Meat Animal Research Center are:

1. Obtain basic knowledge required for understanding and maximizing metabolic efficiency of growth, reproduction and lactation in beef cattle, sheep and swine.
2. Develop and implement technology to increase the amount and nutritional quality, of beef, lamb and pork per unit of available feed and energy resource for maximum consumer acceptability.

Each of the above goals requires multidisciplinary efforts among scientists in other disciplines including Physiology, Breeding and Genetics, Meat Science and Technology, Agricultural Engineering, Production Systems, and Herd Health Management. In addition, the efforts of Technical Support Personnel and Livestock Operations Personnel in carrying out the day to day tasks and in coordinating the many facets of an animal research program are essential in attainment of the stated goals.

### The Nutrition Research Unit Annual Research Summary Covering the Period January 1985 - June 1986

The research described in this annual report was completed or underway in 1985 and early 1986. Previous annual Summaries of Research in Nutrition have been published for 1984, 1983, 1982, 1981, 1980, 1979. The report covers research in beef cattle, sheep and swine. This method of disseminating current research results for direct use in the livestock industry has been well accepted by readers who might not have occasion to read the scientific literature in which the research results from Roman L. Hruska U.S. Meat Animal Research Center (USMARC) are reported in detail.

This annual summary is intended to complement and supplement the USMARC triennial Beef Cattle, Sheep and Swine Research Reports which are published regularly through the efforts of scientists in all disciplines at USMARC in cooperation with the University of Nebraska Institute of Agriculture and the Agricultural Experiment Station. Sheep Research Program Report No. 2 was published in 1984, Beef Research Progress Report No. 2, 1985, and Swine Research Progress Report No. 2 in 1986, covering all disciplines associated with each respective animal species.

In addition to the scientists in the Nutrition Unit, scientists from other research units contributed significantly to the research reported in this Summary. The multidisciplinary nature of the research and the key roles of specific scientists in other units can be appreciated by noting the authorship and titles of manuscripts listed in the Publication List at the end of this report.

## Biographical Sketches and Research Interests of Scientists in Nutrition

Currently, there are six scientists assigned to the Nutrition Research Unit. They are listed below along with a statement of their educational background and experience and their research interests. Dr. Robert R. Oltjen, Director of USMARC, is also a nutritionist and has a distinguished record of attainment in ruminant nutrition research. His counsel and inputs to the nutrition research program are valuable to, and appreciated by, the Nutrition Research Unit.

Dr. Joan H. Eisemann

Title - Research Physiologist

Education and Experience - B.S. 1975, Nutritional Sciences, University of Connecticut,  
M.S. 1978, Animal Nutrition, Cornell University,  
Ph.D. 1982, Nutritional Biochemistry, Cornell University,  
Postdoctoral 1982-1984, Ruminant Nutrition Laboratory, USDA, Beltsville, Maryland,  
RLHUSMARC - 1984 to present

Research Interests: Nutritional and hormonal regulation of protein and lipid accretion in growing animals; post-absorptive regulation of nutrient use by body tissues; mode of action of growth promotants.

Dr. Calvin L. Ferrell

Title - Research Animal Scientist

Education and Experience - B.S. 1971, Animal Science, Oklahoma State University  
Ph.D. 1975, Nutrition, University of California, Davis  
RLHUSMARC - 1975 to present

Research Interests: Utilization of dietary energy for various physiological processes including maintenance, growth, reproduction and lactation by farm livestock.

Dr. Jerome C. Pekas

Title - Research Physiologist

Education and Experience - B.S. 1957, Animal Science, North Dakota State University  
M.S. 1958, Animal Nutrition, University of Florida  
Ph.D. 1961, Animal Nutrition, Iowa State University  
Animal Physiologist, 1961-1964, Agriculture Research Laboratory, Oak Ridge, Tennessee  
Animal Physiologist, 1964-1966, Battelle Memorial Institute, Richland, Washington  
Research Physiologist, 1966-1980, Metabolism and Radiation Laboratory, USDA, ARS, Fargo, North Dakota  
RLHUSMARC - 1980 - present

Research Interests: Gastroenterology of meat animals. To reveal the fundamental principles involved in the regulation of the digestive system - including appetite, motility, secretions, absorption, epithelial turnover and the endocrine control of the dynamics of these cellular and tissue functions. The ultimate goal is to be able to provide the physiological basis to moderate selected functions by genetic, dietary, physiologic, or pharmacologic manipulations to attain improved performance of meat-producing animals.



Dr. Wilson G. Pond

Title - Research Leader, Nutrition

Education and Experience - B.S. 1952, Animal Science, University of Minnesota

M.S. 1954, Animal Nutrition, Oklahoma State University

Ph.D. 1957, Animal Nutrition, Oklahoma State University

Professor, Department of Animal Science, 1957-78, Cornell University

RLHUSMARC - 1978 to present

Research Interests: Protein and energy nutrition of growing pigs and gestating sows; utilization of high fiber in diets of growing and adult swine; mineral requirements and interactions in animals; factors affecting feed intake and appetite in swine; effect of maternal nutrition on subsequent progeny development.

Dr. Vincent H. Varel

Title - Research Microbiologist

Education and Experience - B.S. 1968, Biological Sciences, Quincy College (Ill)

M.S. 1973, Dairy Science Microbiology, University of Illinois

Ph.D. 1977, Dairy Science Microbiology, University of Illinois

RLHUSMARC - 1977 to present

Research Interests: Characterization and manipulation of lower gastrointestinal tract microflora; anaerobic microbial ecology and metabolism; microbial degradation of forages.

Dr. J. T. Yen

Title - Research Animal Scientist

Education and Experience - B.S. 1964, Animal Science, Taiwan University

M.S. 1970, Animal Nutrition, University of Illinois

Ph.D. 1975, Animal Nutrition, University of Illinois

Post Doctorate 1975-78, University of Missouri

RLHUSMARC - 1978 to present

Research Interests: Mode of action of growth promotants in pigs; absorption of nutrients and metabolites through hepatic portal system in conscious, surgically prepared pigs; vitamin C in swine nutrition; postweaning stress as related to nutrition; and feed intake control in growing and pregnant swine.

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Specific research projects often include one- or two-year Post Doctoral appointments in a support role for the permanent Ph.D. level scientists at USMARC.

Also, a limited number of Pre Doctoral students from cooperating universities may complete the research for the Ph.D. thesis at USMARC.

Dr. Larry Reynolds was on a Post Doctoral appointment from 1983 to 1985 to work with Dr. C. L. Ferrell at USMARC in a Cooperative Agreement with Dr. Stephen Ford, Iowa State University on the project, "Nutritional and Hormonal Factors Affecting Fetal Growth and Development." Dr. Reynolds left USMARC in August 1985 to accept a faculty position in the Department of Animal Science, North Dakota State University, Fargo, North Dakota. Dr. Kim Maruyama was a Visiting Scientist in the Nutrition Unit working with Dr. C. L. Ferrell and

others at USMARC on factors controlling muscle protein degradation and net tissue protein accretion in beef cattle and sheep. Dr. Maruyama left USMARC in late 1985 to accept a faculty position in the Department of Animal Science, University of Hawaii.

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#### Technical Support Personnel in the Nutrition Research Unit

Suzanne Annis - B.S., University of Wisconsin, River Falls.  
 Christi Beach - B.A., William Jewell College, Liberty, MO  
 Sandy Fryda Bradley - B.S., University of South Dakota, M.S., South Dakota State University.  
 Debbie Brown - Secretary, ARS  
 Cindy Felber - B.S., Colorado State University  
 Donna Griess - Secretary, ARS  
 Sherry Hansen - Nutrition Secretary, ARS  
 John Killefer - B.S., Hastings College, Hastings, NE  
 Linda Parnell - Secretary, ARS  
 Debra Robertson - B.S., University of Illinois  
 Joan Rosch - Secretary, ARS  
 Lei-Hwa Yen - B.S., National Taiwan University, M.S., University of Wisconsin

The above personnel contribute an essential dimension to the total Nutrition Research program through their efforts in the separate research programs of individual scientists as well as through broad contributions to the total USMARC research program.

In addition, Ron Mlejnek, Laboratory Operations Manager at USMARC and Jeff Waechter, Supervisor of the Proximate Analysis Laboratory, and their staffs, play a vital role in the program of the Nutrition Unit. The research of individual scientists in the Nutrition Unit is intertwined with the total research effort at USMARC and is dependent on the expert support and cooperation of personnel in Livestock Operations, Data Processing, Meats Operations, other support groups, and Marjorie McAlhany, Information Officer.

We thank Sherry Hansen for her efforts in typing and coordinating this publication.

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## Cattle

Title: Clenbuterol Increases Hind Limb Blood Flow and Oxygen Uptake in Steers. (J. H. Eisemann, G. B. Huntington and C. L. Ferrell)

The objective was to measure acute (day 1) and chronic (day 9) effects of dietary clenbuterol (CLEN) on blood flow (BF) and O<sub>2</sub> uptake (O<sub>2</sub>UP) in hind limbs of four Hereford steers (241 ± 5 kg). Steers had ultrasonic flow probes on the descending aorta and catheters in the descending aorta and vena cava (all distal to the renal vessels). Design was a single reversal with two 9-day periods of control or 8 mg CLEN/steer/day with 5 days between periods. Steers were fed every 6 hours in equal meals. Heart rate (HR), BF, arterial (A) and venous (V) O<sub>2</sub> were measured every 30 minutes for one feeding interval. Steers ate all feed offered during measurements. On day 1, measurements were during initial CLEN consumption. Daily intake was 3.87 ± .09 kg dry matter, 11.46 Mcal ME and 712 g crude protein per steer. Steers gained 20 ± 2 kg during the study. On day 1, HR and BF rapidly doubled following initial CLEN consumption. On day 9, HR and BF were chronically elevated, showing no increase following feeding. Increased O<sub>2</sub>UP in steers fed CLEN was due to increased BF (day 1 and day 9) as well as altered O<sub>2</sub> extraction (day 9). By day 9, steers reached a new steady state involving a change in tissue sensitivity to CLEN shown by lack of acute response to the same dose of CLEN received on day 1.

	Acute (day 1)				Chronic (day 9)			
	Control	CLEN	s <sub>d</sub>	P<	Control	CLEN	s <sub>d</sub>	P<
HR, beats/min	91	150	3	.01	86	114	2	.01
BF, liter/min	6.61	11.64	.46	.01	5.62	8.26	.17	.01
A O <sub>2</sub> , mM	5.54	5.98	.21	.12	5.68	5.54	.17	.47
O <sub>2</sub> A-V, mM	1.92	1.40	.22	.11	2.40	1.99	.09	.03
O <sub>2</sub> UP, mmol/min	12.10	15.71	1.14	.06	13.41	16.47	.98	.06

Title: Tissue Protein Synthesis Rates in Beef Steers Injected with Placebo or Bovine Growth Hormone. (J. H. Eisemann, A. C. Hammond, T. S. Rumsey and D. E. Bauman)

The objective was to measure rates of protein synthesis in individual tissues of 10 Hereford x Angus steers (296 ± 3 kg, 5 pairs) given daily subcutaneous injections of bovine growth hormone (bGH, 29.2 IU/day), or placebo (P) for 19 days. Dry matter intakes were 6.81 ± .12 kg/day (2.49 Mcal calculated ME and 127 g crude protein/kg dry matter). On the last day of treatment steers received a 6.3-hour intrajugular infusion of 1-<sup>14</sup>C-leucine. Just before the end of infusion, steers were anesthetized and tissue samples collected (elapsed time was 9 min). The specific radioactivity of leucine in plasma and protein and nonprotein fractions of tissue was determined. Means are presented for P followed by bGH treatment. Empty body weight (EBW, P<.1) and liver, longissimus dorsi, and small intestine weights (P<.05) were greater in bGH treated steers (261 vs 273 kg, 4364 vs 4643 g, 3586 vs 3966 g, 3688 vs 4214, respectively). Fractional synthesis rate (FSR), g protein synthesized/day (PS), g PS as percent of whole body protein synthesis (WBS)

and tissue weight as percent EBW for tissues sampled (SEM) are listed in the following table. Tissue PS as percent WBS and tissue weight as percent EBW were similar for muscles but not for liver and small intestine. Fractional rates of PS tended to be higher in all tissues from bGH treated animals.

	FSR			gPS/d			gPS as % WBS			Tissue weight as % EBW		
	P	bGH	SEM	P	bGH	SEM	P	bGH	SEM	P	bGH	SEM
Liver	.244	.272	.045	191	228	37	13.9	14.3	2.3	1.7	1.7	.04
Biceps femoris	.019 <sup>a</sup>	.023 <sup>a</sup>	.002	14.5	17.8	1.5	1.0	1.2	.1	1.5	1.5	.04
Longissimus dorsi	.023	.027	.002	16.6	20.6	1.8	1.2	1.3	.1	1.4	1.5	.03
Triceps brachii	.025 <sup>b</sup>	.028 <sup>b</sup>	.001	9.3	9.7	.8	.7	.6	.06	.7	.7	.04
Small intestine	.884	1.126	.204	365	549	60	27.0	35.3	6.3	1.4 <sup>c</sup>	1.5 <sup>c</sup>	.04

Means within a row similar superscripted differ as follows: <sup>a</sup>  $p = .10$ ; <sup>b</sup>  $p = .11$ ; <sup>c</sup>  $p < .05$ .

Title: Effect of Bovine Growth Hormone Administration on Metabolism of Growing Hereford Heifers: Dietary Digestibility, Energy and Nitrogen Balance. (J. H. Eisemann, H. F. Tyrrell, A. C. Hammond, P. J. Reynolds, D. E. Bauman, G. L. Haaland, J. P. McMurtry and G. A. Varga)

The objective was to determine the effect of daily s.c. injection of bovine growth hormone (bGH) on nitrogen and energy balance in six Hereford heifers. In addition, effects on urinary excretion of 3-methylhistidine and hydroxyproline and on serum mineral concentrations were monitored. A single reversal design was used with two 14-day injection periods of placebo or bGH (29.2 IU/day). Measurements were made on day 8-14 of each period. Injection of bGH did not alter apparent digestibility of dry matter, energy or nitrogen, nor urinary excretion of 3-methylhistidine or hydroxyproline. Serum concentrations of calcium, phosphorus and magnesium were normal with bGH treatment. Nitrogen retention was higher and urinary nitrogen excretion was lower when the heifers were injected with bGH than with the placebo demonstrating an effect of bGH on postabsorptive metabolism of nitrogen. Total energy balance was not altered by treatment. Energy retained as protein was higher after bGH treatment than after the placebo, implying decreased energy retained as fat and demonstrating a role for GH in altering energy partition in growing animals. Total heat production was not altered by treatment indicating no change in the gross efficiency of metabolizable energy use with bGH treatment.

Title: Effect of Bovine Growth Hormone Administration on Metabolism of Growing Hereford Heifers: Protein and Lipid Metabolism and Plasma Concentrations of Metabolites and Hormones. (J. H. Eisemann, A. C. Hammond, D. E. Bauman, P. J. Reynolds, S. N. McCutcheon, H. F. Tyrrell, and G. L. Haaland)

The objectives were to determine the effects of daily injection of bovine growth hormone (bGH) on the metabolism of [1-<sup>14</sup>C]-leucine and [1-<sup>14</sup>C]-palmitate and on hormone and metabolite concentrations in growing Hereford heifers. The experimental design was a 28-day single reversal with two 14-day injection periods of placebo or bGH. Energy intake was restricted



to a level slightly above maintenance. Injection of bGH did not affect circulating concentrations of glucose,  $\beta$ -hydroxybutyrate, urea nitrogen, prolactin, triiodothyronine or thyroxine. Plasma concentrations of insulin and nonesterified fatty acids (NEFA) were chronically elevated whereas leucine concentration was chronically decreased after 1 week of bGH injection compared to placebo injection. Leucine oxidation was lower and whole body protein synthesis was higher during bGH injection than during placebo injection. There was an increase in both total irreversible loss and oxidation of NEFA during bGH injection compared to placebo injection. These data suggest mobilization of stored fatty acids and increased reliance on NEFA to provide energy for cellular processes. The dual and reciprocal effect of bGH on nitrogen and NEFA metabolism demonstrate its role as a homeorhetic regulator, affecting metabolism of several body tissues to support lean body accretion in Hereford heifers at near-maintenance intake of metabolizable energy.

Title: Effect of Growth Hormone on Plasma Concentrations and Excretion of Metabolites in Steers. (A. C. Hammond, J. H. Eisemann, T. S. Rumsey, and D. E. Bauman)

This study investigated effects of daily subcutaneous injections of bovine growth hormone (GH, 29.2 IU/day) on plasma concentrations of urea N (PUN), creatinine (CRE), ammonia N (NH<sub>3</sub>-N),  $\alpha$ -amino N ( $\alpha$ -NH<sub>2</sub>) and on urinary excretion of hydroxyproline (OHP), 3-methylhistidine (3MH) and CRE in 12 Hereford x Angus steers (295  $\pm$  5 kg). Steers were fed six times daily a pelleted diet (2.49 Mcal calculated ME and 127 g crude protein/kg dry matter) at 234 kcal ME/kg<sup>.75</sup> liveweight. Experimental design was a 28-day switchback with two 14-day injection periods of placebo (C) or GH. Plasma was collected every 20 minutes for 8 hours on day 14 and urine collected on day 9-13 of each period. Results are presented in the table. The decrease in PUN and trend toward decreased  $\alpha$ -NH<sub>2</sub> are consistent with increases in N retention and whole body protein synthesis rate and a decrease in leucine oxidation rate previously reported for these animals. Excretion of OHP and 3MH, indices of collagen and myofibrillar protein breakdown, respectively, indicated no change in breakdown rate of these proteins. There was no change in plasma NH<sub>3</sub>-N, plasma CRE and CRE excretion. We conclude that exogenous GH affects protein metabolites in steers in ways consistent with increased protein synthesis and accretion.

Metabolite	C	GH	SE	P
PUN (mg/100 ml)	9.66	7.42	.57	<.01
CRE (mg/100 ml)	1.16	1.10	.06	>.10
NH <sub>3</sub> -N (mg/L)	3.32	3.19	.33	>.10
$\alpha$ -NH <sub>2</sub> (mM)	2.15	1.96	.19	=.06
OHP (mmoles/day)	5.06	5.23	.30	>.10
3MH (mmoles/day)	.67	.64	.02	>.10
CRE (g/day)	11.7	11.3	1.2	>.10

Title: Growth Hormone Administration Enhances Extrathyroidal Thyroxine-5'-Monodeiodinase Activity in Beef Cattle. (S. Kahl, T. S. Rumsey, J. H. Eisemann, A. C. Hammond, J. Bitman, and D. E. Bauman)

This study examined the effect of bovine growth hormone (bGH) on plasma

thyroxine ( $T_4$ ) and triiodothyronine ( $T_3$ ) concentrations and on liver and kidney thyroxine-5'-monodeiodinase activity (TMA, ng  $T_3$  generated  $\cdot h^{-1} \cdot mg$  protein $^{-1}$ ) of growing beef cattle. In a preliminary trial, samples were obtained at slaughter from two saline-injected and two bGH-injected (29.2 IU/day for 14 days) Hereford heifers (398 kg average slaughter weight) with one heifer in each treatment fed at maintenance energy and the other at twice maintenance energy. In a larger trial, samples were obtained from six saline-injected and six bGH-injected (29.2 IU/day for 19 days) Hereford steers (331 kg average slaughter weight) fed at 1.8 times maintenance energy. Tissue TMA was determined by measuring  $T_3$  generated during incubation of  $T_4$  (1.3  $\mu M$ ) with tissue homogenates or microsomal preparations in the presence of 2 mM dithiothreitol. Blood plasma from steers was obtained hourly from 0800 to 1600 hours on the last day of injection. Plasma was assayed for  $T_4$  and  $T_3$  by RIA. In heifers, bGH increased TMA in liver and kidney 2.86 and 1.21 times, respectively. In steers, bGH increased TMA in liver homogenates from 2.83 to 4.14 ( $P < .05$ ) and in liver microsomal preparations from 27.3 to 32.7 ( $P < .02$ ). Bovine GH also increased TMA in kidney homogenates from .87 to 1.48 ( $P < .10$ ) and in kidney microsomal preparations from 16.4 to 23.0 ( $P < .02$ ). Plasma  $T_4$  (69.6 vs 72.8 ng/ml) and  $T_3$  (1.08 vs 1.23 ng/ml) trended greater in bGH-treated steers. Present data suggest that bGH acts in extrathyroidal tissues of cattle to increase the conversion of  $T_4$  to  $T_3$ , the most active thyroid hormone involved in metabolism and animal growth.

Title: Thermophilic and Mesophilic Methane Production from the Alga Spirulina Maxima. (V. H. Varel, T. H. Chen and A. G. Hashimoto)

The feasibility of producing methane by using the blue green alga Spirulina maxima as the sole substrate was investigated in 200 ml working-volume anaerobic digesters maintained at 35 and 55°C. Digesters were fed once-per-day with 2.25% volatile solids at retention times of 8, 12, and 16 days. Digester contents were mixed for one minute before and after feeding. After 3-volume turnovers, samples were obtained on four consecutive days. Methane production rate (liters of methane per liter of digester per day) and methane yield (liters/g of COD fed) at 35°C were, 0.47 and 0.09, 0.41 and 0.15, and 0.31 and 0.15 at the respective retention times of 8, 12, and 16 days; at 55°C they were, 0.20 and 0.05, 0.31 and 0.11, and 0.19 and 0.09, respectively. The methane yield after 105 days of batch fermentation was 0.22 liters  $CH_4$  per g COD fed. COD degradation at these retention times and temperatures was between 23 and 40%, ammonia nitrogen between 1.12 and 1.86 g/liter and alkalinity between 7.0 and 7.8 g  $CaCO_3$ /liter. The concentration of total volatile acids at 35°C were 4.07, 2.58 and 3.13 at the respective times of 8, 12, and 16 days; at 55°C they were 6.78, 4.18, and 4.07, respectively. These studies indicate that Spirulina maxima can be used as a sole nutrient for methane production at mesophilic and thermophilic temperatures; however, the methane production rates at these retention times are higher at the mesophilic temperature. These rates are significantly lower than those obtainable with cattle waste because maximum loading rates can be greater with cattle waste before digester failure occurs.

Title: Influence of Forage Phenolic Compounds on Ruminal Fibrolytic Bacteria and In Vitro Fiber Degradation. (V. H. Varel and H. G. Jung)

Plant cell walls contain phenolic compounds which have been shown to be toxic

to rumen bacteria and protozoa. In vitro cultures of rumen microorganisms were used to determine the effect of cinnamic acid and vanillin on the digestibility of cellulose and xylan. Previously, we have shown that cinnamic acid and vanillin depressed in vitro dry matter disappearance of cellulose 14 and 49%, respectively, when rumen fluid was the inoculum. The number of viable Bacteroides succinogenes cells, the predominant cellulolytic organism, was three-fold higher for fermentations which contained vanillin than for control fermentations.

When xylan replaced cellulose as the substrate, a 14% decrease in the digestibility of xylan was observed with vanillin added; however, the number of viable xylanolytic bacteria cultured from the batch fermentation was 10-fold greater than controls. The doubling time of B. succinogenes was increased from 2.32 to 2.58 hours when vanillin was added to cellobiose medium; and absorbance was one-half that of controls after 18 hours. The growth rate of Ruminococcus albus and R. flavefaciens was inhibited more by p-coumaric acid than vanillin, although no reduction of final absorbance was observed in their growth cycles. Vanillin, and to a lesser extent cinnamic acid, appeared to prevent the attachment of B. succinogenes cells to cellulose particles, but did not affect dissociation of cells from the particles. B. succinogenes, R. albus, R. flavefaciens and Butyrivibrio fibrisolvens all modified the parent monomers cinnamic acid, p-coumaric acid, ferulic acid and vanillin, with B. fibrisolvens causing the most extensive modification. These results suggest that phenolic monomers can inhibit digestibility of cellulose and xylan possibly by influencing attachment of the fibrolytic microorganisms to fiber particles. The reduced bacterial attachment to structural carbohydrates in the presence of vanillin may generate more free-floating fibrolytic organisms, thus, giving a deceptively higher viable count.

Title: Urea Production and Urea Cycle Enzyme Activities of Maternal Liver, Fetal Liver and Placental Tissues of Cows. (C. L. Ferrell, D. A. Robertson and L. P. Reynolds)

To determine urea production and urea cycle enzyme activities, maternal liver (ML), fetal liver (FL) and placenta (P) of beef cows (n=7) were obtained at slaughter on day 162  $\pm$  4 of gestation. Activities ( $\mu$ mol product produced/hour) of carbamoyl phosphate synthetase (CPS), ornithine transcarbamoylase (OTC), argininosuccinate synthetase (AS), argininosuccinase (Aa), and arginase (A) were determined for homogenates of each tissue. Activities per g of ML, FL and P were 182.0  $\pm$  16.9, 36.6  $\pm$  4.3 and 9.7  $\pm$  1.1 for CPS, 7101.0  $\pm$  1072.6, 1127.7  $\pm$  86.1 and 15.8  $\pm$  1.5 for OTC, 122.2  $\pm$  9.8, 43.3  $\pm$  13.2 and 10.8  $\pm$  .7 for AS, 239.4  $\pm$  17.0, 39.4  $\pm$  4.6 and 8.9  $\pm$  .7 for Aa and 51243.3  $\pm$  2521.7, 30526.0  $\pm$  6724.8 and 3120.8  $\pm$  1214.0 for A, respectively. Thus, activities of all urea cycle enzymes were observed in each tissue with ML>FL>P (P<.01). In addition, 1 g of each tissue was minced and incubated in continuously-oxygenated (95% O<sub>2</sub>, 5% CO<sub>2</sub>) medium 199 for 1 hour to evaluate in vitro production or utilization of urea, glucose and lactate. Net production or utilization of metabolites ( $\mu$ mol/h/g) by ML, FL and P were 6.22  $\pm$  .17, 3.99  $\pm$  .19 and 5.18  $\pm$  .35 for urea, 104.82  $\pm$  8.15, 2.97  $\pm$  .35 and -3.68  $\pm$  .47 for glucose and 17.48  $\pm$  1.66, 20.73  $\pm$  1.94 and 26.38  $\pm$  1.67 for lactate, respectively. Urea production thus represented 5.1, 10.9 and 58.2% of the least active urea cycle enzyme for ML, FL and P, respectively. Total wet weights of ML, FL and P were 5448  $\pm$  422, 131  $\pm$  16 and 1764  $\pm$  193 g, respectively. Total



in vitro capacity to produce urea (net production x wet weight; mmol/h) was greater ( $P < .01$ ) for ML and PL ( $33.82 \pm 2.69$  and  $9.49 \pm 1.62$ ) than for FL ( $.53 \pm .08$ ). In agreement with data previously obtained in vivo, these results indicate that placental tissues are the major site of urea production within the gravid bovine uterus.

Title: Growth Hormone, Insulin and Glucose Concentrations and Secretory Patterns in Bovine Maternal and Fetal Plasma. (L. P. Reynolds, C. L. Ferrell, D. A. Robertson, and J. Klindt)

In study 1, catheters were implanted in the uterine artery (UA) of the gravid horn and in a fetal placental vein on day  $132 \pm 1$  ( $n=6$ ) and  $245 \pm 2$  ( $n=5$ ), or in the UA and an umbilical vein (UmbV) on day  $176 \pm 1$  ( $n=8$ ) and  $220 \pm 1$  ( $n=9$ ) of gestation in Hereford cows. In study 2, UA and UmbV catheters were implanted in Hereford cows ( $n=7$ ) on day  $191 \pm 1$  of gestation. Four to 12 days after surgery, samples were obtained from each catheter every 30 min to 3 hours. Plasma concentrations of growth hormone (GH, ng/ml), insulin (I,  $\mu$ U/ml) and glucose (GLUC, mM) were determined in samples pooled within vessel (study 1) or in individual samples (study 2). In study 1, I and GLUC remained constant across day of gestation and averaged  $21.7 \pm 1.0$  and  $4.6 \pm .1$  in UA and  $6.6 \pm .3$  and  $2.2 \pm .1$  in UmbV. Uterine arterial GH were less ( $P < .05$ ) on day 137 and 250 ( $2.6 \pm .1$  and  $1.8 \pm .2$ ) than on day 180 and 226 ( $3.8 \pm .2$  and  $3.1 \pm .4$ ). Umbilical venous GH were similar on day 137 and 180 ( $23.9 \pm 5.5$  and  $37.8 \pm 4.7$ ) and less ( $P < .05$ ) than on day 226 and 250 ( $58.5 \pm 4.0$  and  $49.3 \pm 5.5$ ) which also were similar. In study 2, I and GLUC in each cow were constant during the 3 hour sampling period and averaged  $11.5 \pm .3$  and  $3.9 \pm .1$  in UA and  $5.8 \pm .2$  and  $1.9 \pm .1$  in UmbV. Uterine arterial GH remained constant (overall mean  $3.1 \pm .3$ ), whereas pulsatile GH were observed in UmbV (overall mean  $64.3 \pm 2.6$ ; pulse height 10 to 60 ng/ml; pulse frequency 2/3 h). In both studies, even though GH were 10- to 20-fold greater ( $P < .01$ ) and I were 2- to 3-fold less ( $P < .01$ ) in UmbV than in UA, the fetus was hypoglycemic ( $P < .01$ ) compared with maternal plasma. Pulsatile secretion of GH was observed in the bovine fetus but not in maternal plasma.

Title: Effects of Chronic Environmental Heat Stress on Blood Flow and Nutrient Uptake of the Gravid Bovine Uterus and Foetus. (L. P. Reynolds, C. L. Ferrell, J. A. Nienaber, and S. P. Ford)

To evaluate the effects of chronic environmental heat stress during mid-gestation on gravid uterine and foetal metabolism, mature Hereford cows were assigned to control ( $n=8$ ) or heat stress ( $n=5$ ) treatments beginning on day 100 of gestation. Uterine and umbilical blood flows were estimated by the steady-state diffusion procedure on day  $169 \pm 4$  of gestation. Oxygen ( $O_2$ ), glucose, lactate,  $\alpha$ -amino nitrogen and urea nitrogen concentrations were determined for uterine and umbilical blood samples collected during this procedure. Foetuses and foetal fluids were collected on day  $174 \pm 4$ .

Uterine and umbilical blood flows were reduced and foetal weight also was less for heat-stressed than for control cows. In addition, foetal liver weight as a proportion of foetal weight and total foetal liver RNA and protein were less for heat-stressed cows. Uterine and umbilical arterial-venous concentration differences in metabolites were similar between the two groups. Uterine, foetal and utero-placental uptake or secretion rates of the metabolites



measured in this study were reduced in the heat-stressed cows, primarily because of differences in blood flow. Thus, chronic heat stress during mid-gestation had an adverse effect on foetal development resulting, at least in part, from decreased uterine and umbilical blood flows, which led to a reduction in uterine, utero-placental and foetal nutrient uptake or secretion rates.

Title: Metabolism of the Gravid Uterus, Foetus and Utero-Placenta at Several Stages of Gestation in Cows. (L. P. Reynolds, C. L. Ferrell, Debra A. Robertson, and S. P. Ford)

To quantify changes in rates of metabolism and nutrient uptake of gravid uterine, foetal and utero-placental tissues throughout gestation, mature Hereford cows received surgery at  $132 \pm 0.6$  (n=12),  $176 \pm 0.5$  (n=8),  $220 \pm 0.4$  (n=11) and  $245 \pm 1.5$  (n=7) days after mating. Indwelling catheters were implanted into a uterine artery and vein of all cows. Foetal catheters also were implanted into an umbilical vein and foetal femoral artery and vein (days 176 and 220) or into a placental artery and two placental veins (days 132 and 245). Approximately 5 days after surgery, deuterium oxide was infused into a foetal femoral venous or placental venous catheter during a 3 hour period to quantify uterine and umbilical blood flows by steady-state diffusion methods. Oxygen, glucose, lactate, and  $\alpha$ -amino acid nitrogen concentrations were determined for uterine and foetal blood samples collected during this procedure.

Uterine blood flow increased 4.5-fold (2.92 - 13.18 l/min) and umbilical blood flow increased 21-fold (0.28 - 5.86 l/min) during the interval of gestation studied. The relative rate of increase of umbilical blood flow was about twice as great as that of uterine blood flow. Uterine arterial and umbilical venous concentrations as well as uterine arterial-venous and umbilical venous-arterial concentration differences in metabolites changed little with stage of gestation. However, because rates of blood flow increased, uptakes of  $O_2$ , glucose and  $\alpha$ -amino N by the gravid uterus and foetus increased as gestation advanced. The proportion of gravid uterine uptakes utilized by the foetus increased from day 137 to 226 for  $O_2$  (24 - 58%) and from day 137 to 180 for glucose (4 - 19%), then remained relatively constant. The proportion of gravid uterine  $\alpha$ -amino N uptake utilized by the foetus remained relatively constant and averaged 60%. A net secretion of lactate from the utero-placenta to the uterine and foetal circulations was observed and increased as gestation advanced. These data indicate that increased rates of uptake or secretion of metabolites by tissues of the gravid uterus can be explained primarily by increased rates of uterine and umbilical blood flows.

Title: Transplacental Diffusion and Blood Flow of Gravid Bovine Uterus. (L. P. Reynolds, C. L. Ferrell and S. P. Ford)

Electromagnetic blood flow transducers and uterine arterial, uterine venous, umbilical venous, fetal femoral arterial, and fetal femoral venous catheters were implanted in 11 cows on day  $161 \pm 4$  of gestation. Antipyrine (0.66 M) plus NaCl (0.16 M) dissolved in deuterium oxide ( $D_2O$ ), or  $H_2O$ , was infused at a constant rate into the fetal femoral vein catheter. Concentrations of antipyrine and  $D_2O$  in uterine arterial and venous blood antipyrine in fetal arterial and umbilical venous blood, as well as middle uterine arterial blood flow (electromagnetic transducer), were determined. Antipyrine and  $D_2O$  gave

similar estimates (steady-state diffusion method) of gravid uterine blood flow. In addition, the slope of the regression of  $D_2O$  on antipyrine estimates was not different ( $P > 0.10$ ) from one. Electromagnetic transducers gave estimates of uterine blood flow that were 32 - 42% of those obtained with steady-state diffusion but were correlated ( $P < 0.05$ ) with estimates obtained by use of both antipyrine and  $D_2O$ . The transplacental clearance rate of antipyrine was similar (per kg placenta) to that observed in ewes. It was suggested that the maternal and fetal microvasculatures of the bovine placenta could have a concurrent arrangement with vascular shunts or maldistribution of flows, as has been suggested for the ewe.

Title: Cow Type and the Nutritonal Environment: Nutritional Aspects.  
(C. L. Ferrell and T. G. Jenkins)

Numerous studies have been reported that relate to the influence of cattle type on production efficiency; however, most reported studies have been concerned with output characteristics. This review concentrates on the influence of cattle type on the input requirements and more specifically, energy requirements. Data are presented that show that energy is required for maintenance, growth, gestation and lactation and requirements for each of these functions vary among cattle types. Data are presented that suggest 70 to 75% of total annual energy requirements are required for maintenance functions and variation in requirements for maintenance appear to be greater than variation in requirements for growth, gestation or lactation. In general, variation in maintenance requirements appears to be positively associated with genetic potential for measures of production, e.g., rate of growth or milk production. Reported results suggest that animals having genetic potential for high productivity may have less advantage or be at a disadvantage in a more restrictive environment, suggesting the need for synchronization of production environment and germ plasm resources. Some of the sources of variation in maintenance requirements have been discussed. Data are cited that suggest little of the variation in maintenance energy expenditures is attributable to variation in total body composition per se. However, considerable evidence has accumulated to show that a relatively large proportion of maintenance energy expenditures can be attributed to energy expenditures of visceral organs, especially the liver and gastrointestinal tract. High rates of energy expenditures of these tissues appear to be directly or indirectly associated with the high rates of protein synthesis in these tissues. Greater use of differing research approaches and assimilation of the results are needed to develop an understanding of the reasons for variation among animals in maintenance energy expenditures or energetic efficiency.

Title: Energy Utilization by Hereford and Simmental Males and Females.  
(C. L. Ferrell and T. G. Jenkins)

Postweaning metabolizable energy intake, growth of empty-body chemical components and efficiencies of energy utilization were evaluated for Hereford intact males (17) and females (16) and Simmental intact males (15) and females (16) during a 212-day feeding period. Within each breed x sex subclass, animals were assigned to one of three levels of metabolizable energy (ME) intake: (1) 544 kJ/kg  $M^{0.75}$  per day, (2) 795 kJ/kg  $M^{0.75}$  per day, and (3) ad libitum. Body composition of each animal was estimated at the beginning and end of the feeding period by deuterium oxide dilution.

Protein and water gain of Hereford and Simmental cattle were similar at restricted levels of intake but were greater for Simmental than for Hereford cattle at ad libitum intakes. Similarly, rates of protein and water gain tended to increase more rapidly in response to increased energy intake by males than by females. Hereford males gained fat and energy slightly more rapidly than Hereford females, but Simmental males gained fat and energy at slower rates than Simmental females.

Males had higher maintenance requirements and tended to use ME with less efficiency for maintenance and gain than females. Hereford cattle had lower maintenance requirements and used ME with greater efficiency for both maintenance and gain than Simmental cattle.

Title: Relationship of Components of the Body Among Mature Cows as Related to Size, Lactation Potential and Possible Affects on Productivity.  
(T. G. Jenkins, C. L. Ferrell and L. V. Cundiff)

Attributes of lactation and weight of components of the empty body were analyzed to evaluate relationships between performance potential of various breeds or breed crosses and the proportion of empty body components relative to slaughter weight. Differences in major internal organs attributable to breed, breed cross, level of feed intake, mature body size, and milk production potential were observed. Milk yield was positively related to proportion of lung tissue, tended to be positively related to head and liver tissues but was negatively related to the proportion of warm carcass. As estimated from a three breed diallel, significant additive breed direct effects were observed for several empty body components. In general, heterosis tended to be non-significant for all proportions of body components with the exception of proportion of head, fore+hind hooves and lung tissue. Breed crosses characterized as having greater potential for mature weight were heavier at slaughter and had a greater proportion of structural components such as head, hide and fore+hind hooves. Differences among visceral organs associated with production potential for size and milk production are discussed relative to the possible affect on basal energy expenditure and the effect these differences may have on the energy requirements for a cow/calf livestock enterprise.

Title: Effects of Sex Condition, Genotype and Diet on Bovine Growth and Carcass Characteristics. (J. D. Crouse, C. L. Ferrell and L. V. Cundiff)

A study was made of growth performance and carcass merit of castrate or intact male Angus or Simmental cattle fed one of two diets differing in energy density. Response variables were statistically adjusted to a constant percentage of rib fat. Right sides of carcasses were electrically stimulated. Differences in live-animal weights between intact Angus and intact Simmental were greater ( $P < .01$ ) than when the breed comparison was made within the castrated males. Differences in live-animal weights of Angus and Simmental cattle were also greater ( $P < .01$ ) when the high-energy diet was fed than when the low-energy diet was fed. The earlier maturing Angus cattle, castrate males and cattle fed the high-energy diet attained the compositional slaughter point (33.5% rib fat) more rapidly and tended ( $P > .05$ ) to have improved feed efficiency in comparison with Simmental cattle, intact males and cattle fed the low-energy diet, respectively. Hastening the fattening rate of an animal



also reduced ( $P < .01$ ) carcass maturity scores, brightened ( $P < .01$ ) lean meat color, and improved ( $P < .05$ ) firmness and texture of the lean. However, hastening the rate of fattening reduced ( $P < .01$ ) carcass weight and longissimus muscle area. Although not statistically significant, the longissimus muscle of electrically stimulated sides tended ( $P > .05$ ) to possess less heat ring and to be lighter in color, finer textured and softer.

Title: Role of Insulin and Glucose on Metabolite Uptake by the Hind Half of Beef Steers. (Ronald L. Prior, Gerald B. Huntington and Paul J. Reynolds)

Arterial and venous concentrations, extraction ratios and uptake of glucose, L-lactate and volatile fatty acids were measured in the hind half of four beef steers (340 to 360 kg) fitted with indwelling catheters in the posterior aorta and vena cava. The steers were fed hourly a pelleted, 85% concentrate diet. Treatments were control, iv infusion of insulin (1.4 IU/min) and iv infusion of glucose (149.4 mmol/h). Arterial blood concentration of glucose decreased from 3.23 mM (control) to 1.51 mM (insulin), then increased to 4.29 mM (glucose). Extraction ratio of glucose increased about three-fold from 2.6 and of L-lactate decreased about four-fold from 9.2 during insulin infusion, then returned toward control values during glucose infusion. Extraction ratios of acetate (39), propionate (45) and butyrate (28) were similar among treatments. Uptake (two steers) of glucose from blood (mmol/h) increased from 38 (control) to 76 (insulin) and 99 (glucose). Uptake of acetate, propionate and butyrate from plasma (mmol/h) was, respectively, 105, 6.5, .93 (control; 170, 11.9, 3.53 (insulin and 134, 10.9, 3.12 (glucose). Rates of uptake of glucose and propionate during control were slower ( $P < .05$ ) than rates during insulin or glucose infusion; nonsignificant changes in uptake of butyrate followed a similar pattern. Uptake of L-lactate tended to be inversely related to uptake of glucose. Treatments did not affect uptake of acetate or valerate. Uptake of all metabolites except valerate was positive, indicating net use by the hind half.

Title: Net Absorption of Amino Acids by Portal-Drained Viscera and Hind Half of Beef Cattle Fed a High Concentrate Diet. (Gerald B. Huntington and Ronald L. Prior)

Two experiments were conducted to measure the effect of level of feed intake on net amino acid absorption by portal-drained viscera of six beef heifers with catheters in a mesenteric vein, portal vein and iliac artery (Exp. 1) and to evaluate intrajugular infusion of insulin or glucose on amino acid uptake by hind half of four beef steers with catheters in posterior aorta and vena cava (Exp. 2). Experiment 1 was a replicated 3 x 3 Latin square design. Treatments were calculated intakes of 84, 157 or 225 kcal metabolizable energy (ME/kg<sup>.75</sup>) liveweight. Treatments in Exp. 2 were control (no infusion), insulin infusion (1.4 IU/min for 90 min) and glucose infusion (2.5 mmol/min for 90 min) in that order. Mean liveweight of animals  $\pm$  SE was 295  $\pm$  4 kg (Expt. 1) and 345  $\pm$  15 kg (Exp. 2). The diet used in both experiments was pelleted, 85% concentrate (2.9 Mcal ME/kg dry matter). Blood flow (BF) was measured by dilution of a primed, continuous infusion of para-aminohippuric acid into the mesenteric vein (Exp. 1) or the posterior aorta (Exp. 2). Net uptake or absorption was the product of BF times portal-arterial (Exp. 1) or arteriovenous (Exp. 2) differences in amino acid concentrations in blood. Increased

feed intake caused linear ( $P < .05$ ) increases in net absorption of several amino acids, including lysine, methionine, leucine, and valine (Exp. 1). Feed intake did not affect ( $P > .05$ ) net absorption of glutamate or glutamine. Net absorption of these two amino acids was negative, indicating their use as metabolic fuel by portal-drained viscera. Infusion of insulin or glucose (Exp. 2) did not affect ( $P > .05$ ) uptake of amino acids measured, but arterial concentrations of amino acids except histidine were lower ( $P < .05$ ) during infusion of insulin or glucose than during control. Combination and extrapolation of data from these experiments indicate that about one-half of protein deposition in beef steers fed a high concentrate diet is in the hind half.

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## Swine

Title: Comparative Effects of Dietary Protein and Cholesterol-Fat Content on Genetically Lean and Obese Pigs. (Wilson G. Pond, Jong-Tseng Yen, Harry J. Mersmann, and Wanda M. Haschek)

Interactions of a high fat-high cholesterol diet with low and high dietary protein levels were tested in genetically obese and lean growing pigs. Sixty-four growing swine (32 obese and 32 lean) were utilized in a 9 week experiment in which 4 diets were fed in a 2 x 2 factorial arrangement with two levels of plant protein (8 and 16%) and two levels of fat and cholesterol (0 added or 11% beef tallow - 3% dried egg yolk added). Daily gain and gain to feed ratio were reduced by low protein ( $P < .01$ ), and increased by high fat-high cholesterol. Obese pigs gained weight faster than lean pigs but were less efficient in feed utilization ( $P < .02$ ) except when consuming low protein diets ( $P < .001$ ). Plasma cholesterol was increased by low protein ( $P < .01$ ) and by high fat-high cholesterol ( $P < .02$ ); highest values were in pigs fed low protein-high fat-high cholesterol. Lean pigs showed a greater rise than obese pigs in plasma cholesterol when fed low protein diets, reflecting a higher dietary protein requirement for lean pigs as indicated by plasma total protein, albumin and urea-N responses to diet. Percentage of aortic surface area stained by Sudan IV tended to be higher in lean compared with obese pigs but the difference was not statistically significant ( $P < .25$ ). The data show the hypercholesterolemic effect of dietary protein restriction in growing swine and establish that genetic differences related to body composition and quantitative protein requirement affect the response.

Title: Modern Pork Production. (Wilson G. Pond)

The swine population of the world continues to increase faster than the human population which is near 4.5 billion now and expected to exceed six billion by the year 2000. Although one often hears the assertion that the swine industry is in jeopardy because the pig competes directly with humans for some of the available food supplies, science and technology are creating changes in the pig and in production systems which may assure continued growth of swine numbers and pork consumption worldwide. The swine industry has been greatly transformed over the past few years by advances in knowledge of biology and in housing and management technology; research now in progress will result in even further changes. Population geneticists capitalize on modeling techniques made possible by computer technology and introduce genetically diverse breeding stock into crossbreeding programs. Techniques for estimating backfat and testing for pregnancy by ultrasonic devices, and for predicting subsequent body composition of an animal by appropriate measurement done early in life offer possibilities for faster selection for leanness. Genetic engineering by recombinant DNA techniques shows promise of opening the way to large scale production of hormones, vaccines, amino acids, and enzymes that will have an impact on efficiency of pork production. Laboratory work on muscle and fat cell growth and on controls of cellular protein and fat synthesis and degradation offers the possibility of fuller knowledge of factors controlling growth of muscle tissue in swine. Research on factors associated with high prenatal mortality may make it feasible to increase live births per pregnancy and pigs marketed per sow yearly. Combining the technology that would raise the

average of viable pigs per litter to 11-14, decrease preweaning mortality to 5 to 10%, decrease carcass fat content to 20% and reduce feed per kg of body weight gain to 2.5 kg while continuing to develop technology in housing and equipment, feed processing and handling, animal care, energy efficient production systems, and marketing, assure a continued bright future for the swine industry of the world.

Title: Responses of Rats to Dietary Lead in the Presence or Absence of Natural or Synthetic Zeolites. (W. G. Pond, J. T. Yen and L. Krook)

Forty-eight male and 48 female Sprague-Dawley weanling rats were assigned randomly within sex to six diets as follows: (1) Basal (B), (2) B + 3% clinoptilolite, (3) B + 3% zeolite NaA, (4) B + 200 ppm lead acetate (Pb), (5) B + clinoptilolite + Pb, and (6) B + zeolite NaA + Pb. Body weights were recorded weekly. Diets were fed ad libitum to individually caged rats for 28 days at which time all males were euthanized with diethyl ether and liver, kidney, brain cortex, and femurs were weighed and blood was collected from the abdominal aorta. Kidneys from four rats fed each diet were fixed in 10% buffered formalin, and used for histopathology. Bones and soft tissue were dried, ashed and analyzed for Pb. Females were continued on their respective diets for 8 weeks at which time all females were transferred to the basal diet fed ad libitum through breeding, gestation and a 3-week lactation. Dietary Pb depressed body weight gain, hematocrit and erythrocyte delta-aminolevulinic acid dehydratase activity in males after 4 weeks. The effect was negated by the presence of clinoptilolite or zeolite NaA in the diet. Kidneys of rats fed zeolite NaA showed necrosis, fibroplasia and hyaline body formation in proximate tubules. Lead in the presence of zeolite NaA exacerbated the lesions. Kidneys of rats fed other diets were normal. Reproduction and lactation of females following 8 weeks of dietary Pb exposure were normal and indices of Pb intoxication in pups at birth and weaning were absent. The data indicate no carry-over effects of dietary exposure to 128 ppm Pb during growth on subsequent reproduction or progeny development in rats. The apparent interaction of dietary Pb and zeolite NaA in evoking kidney damage should be further characterized and quantified.

Title: Effect of Obesity per se on Plasma Lipid and Aortic Responses to Diet in Swine. (W. G. Pond, H. J. Mersmann and J. T. Yen)

Thirty-two genetically lean and obese Yorkshire x Duroc crossbred castrated male pigs were divided within genetic line into two groups at 7 weeks of age. Eight pigs within each line were fed a diet low in fat and cholesterol (maize-soybean meal diet fortified with minerals and vitamins). The other group was fed a similar diet containing added beef tallow (11%) and dried egg yolk (1%). All pigs were fed ad libitum for 4 months when one-half of each group was slaughtered. All other pigs were continued on their respective diets at a restricted level of intake for an additional 5 months at which time the protein source of two pigs in each diet groups within each genetic line was changed from soybean meal to casein. After an additional 6 months on their respective diets (16 months total duration of experiment) these pigs were slaughtered. Blood samples were taken monthly or bimonthly for total plasma cholesterol and triglycerides. At slaughter, the aorta was opened, stained with Sudan IV, and the stained area traced and measured planimetrically. Only a moderate rise occurred in plasma cholesterol and triglycerides



of pigs fed high fat-high cholesterol diets. Genetically obese pigs were no more susceptible to diet-induced hypercholesterolemia and to the percentage of the surface area of the aorta stained with Sudan IV than were lean pigs. It is concluded that obesity per se is not necessarily associated with development of atherosclerosis in pigs and that innate ability to metabolize high dietary cholesterol is of greater importance than body fatness in determining the response to diet.

Title: Heritability of Plasma Cholesterol and Triglyceride Concentrations in Swine. (Wilson G. Pond, Harry J. Mersmann and Larry D. Young)

Three-hundred and eighteen female swine representing contemporary commercial swine breeds (34 Chester White, 43 Large White, 42 Landrace, 40 Yorkshire, and 159 four-breed crossbreeds) were used to evaluate genetic variation between and within breeds for levels of plasma cholesterol and plasma triglycerides. Blood was sampled from all pigs after a 16-hour fast at 154 days of age. Plasma cholesterol was measured in all pigs and triglycerides were measured in 232 pigs. Paternal half-sib heritabilities ( $h^2$ ) for plasma cholesterol and plasma triglycerides were  $0.45 \pm 0.23$  and  $1.04 \pm 0.32$ , respectively. Breed differences were not apparent for either trait. Phenotypic and paternal half-sib genetic correlations between the two traits were 0.16 and 0.66, respectively. Neither body weight nor backfat depth were important in affecting the estimate of  $h^2$  for either trait. The relatively high  $h^2$  of total plasma cholesterol and of total triglycerides offers the possibility of developing, through selection, populations of hypercholesterolemic or hypertriglyceridemic swine useful as models for studies directed toward understanding of human cardiovascular disease.

Title: Effects of Level and Source of Dietary Fiber in Gestation on Reproductive Performance and Nutrient Digestibility in Gilts. (W. G. Pond, J. T. Yen and V. H. Varel)

Thirty-two primiparous crossbred gilts (eight gilts fed each of four diets) were used to determine the effect of dietary fiber source and level on their reproductive performance and apparent digestibility of diet constituents and on survival and growth of their progeny. Newborn pigs from dams fed 96% dehydrated alfalfa meal (DAM) from breeding to parturition were smaller and less vigorous than pigs from dams fed a basal corn-soybean meal diet, or similar diets containing 20% corn cobs or 40% DAM. Body weights and backfat depth of dams fed 96% DAM were less at term and after 3 weeks of lactation than those of dams fed other diets. Although the experimental plan was for a daily intake of 1800 g of feed for all gilts, those fed 96% DAM failed to voluntarily consume that amount and were, therefore, fed 1350 g daily through day 110 of pregnancy. Four gilts fed each diet were used to determine apparent digestibility of diet constituents during mid-pregnancy. There was no effect of diet on apparent digestibility of crude protein, neutral detergent fiber, acid detergent fiber, cellulose or ash, but gross energy, ether extract and dry matter digestibility were lower for the 96% DAM diet than for other diets. The number of pigs weaned per litter was unaffected by gestation diet, but progeny of dams fed 96% DAM weighed less at 2 and at 4 weeks of age than progeny of other dams. Daily gain of progeny from 0 to 28 days and from 28 to 63 days was not significantly affected by gestation diet, although progeny of dams fed 96% DAM tended to gain weight at a slower rate during each time



interval. The results confirm the feasibility of using high fiber diets (20% corn cobs or 40% dehydrated alfalfa meal) for gilt reproduction. The source of the alfalfa meal selected for use when fed as the sole source of energy and protein must be considered to ensure adequate digestible energy consumption for normal piglet birth weight and early postnatal growth. Corn cobs fed at 20% of the diet or DAM fed at 40% of the diet are satisfactory constituents of gestation diets for primiparous gilts.

Title: Animal Growth During Liberation from Appetite Suppression.  
(Jerome C. Pekas)

Superalimentation (SA) of swine at 120% (ad libitum = 100%) for 23 days elicited a 40% greater gain of body mass ( $P < .005$ ) than littermate control (C) pigs. The accretion of lean and fat tissues during this excess and rapid growth were about the same as if the animal were allowed to attain the same weight over a longer period by conventional feeding practices.

Superalimentation is defined as feed intake distinctly in excess of normal voluntary intake on a grams-dry-matter-per-kilogram-body-weight basis. The substantial body mass response shows that growth is limited by a lack of nutrient intake (appetite) during normal ad libitum feeding. Either (a) digestion-absorption processes are not saturated during normal feed intake, or (b) digestion and absorption capacities are enhanced during excess food intake; furthermore, either (c) cellular hyperplasia or hypertrophy are not regulated by inherited neuroendocrine factors, or (d) cellular growth is somewhat released from neuroendocrine regulation during periods of excess circulating nutrients.

The overall gain efficiency (kg total gain per kg total alimentation dry matter) during superalimentation was slightly improved (7.3%) but was not significant. Efficiency of the differential gain ( $\Delta$  gain/ $\Delta$  dry matter intake;  $\Delta = \text{SA} - \text{C}$ ) was 25% higher than the overall gain efficiency of the C pigs (0.374 vs 0.300 kg/kg) and suggests that the additional nutrients may have been utilized for growth with greater efficiency than nutrient consumed ad libitum.

Title: Morphometry of the Intestine of the Pig. I. A Method for Complete Circumsection Analysis. (Jerome C. Pekas)

A method and scheme are described to improve precision for quantitation of functional aspects of the intestine by morphometric evaluation of a representative sample hereafter called a circumsection. A circumsection is defined as: all tissue lying within the total circumference of a slice of the intestinal wall transected at a right angle to the long axis of the intestine tube. The quantitative values obtained from these substantial specimens therefore provide a basis for reliable estimations of the organ content of specified cellular masses or of functional surfaces, i.e., villi volume, epithelial surface, crypt mass, muscle mass, etc. The volume, mass, or area of specialized cells can be compared with physiological functions and capacities. These comparisons and relationships are important to investigate the causes and effects of digestion-absorption parameters on performance output of healthy animals--growth, development, reproduction, lactation, work output, etc. The data can also describe responses of the digestive organs (tissues) to various inputs--dietary, environmental, chemical, and physical. The method involves analysis of a montage of photomicrographs of the circumsec-

tion. The method was successful; the data collected demonstrated that the small intestine of the pig has lateral symmetry (left vs right) but is asymmetrical in the opposite plane (mesenteric vs antimesenteric). The asymmetry is especially clear in the ileum and jejunum where significant differences between opposite halves ranged from 7% to 90% of the mean value.

Title: Morphometry of the Intestine of the Pig. II. Circumsection Response to Feeding Schedules. (Jerome C. Pekas)

Weight measurement of the gastrointestinal organs (GIT) and morphometric measurements of circumsections of the small intestine (SI) have demonstrated profound responses to the level of dietary intake. The average response of pigs (all the same live body weight) gaining weight at a moderate rate (treatment LH) relative to pigs losing weight (HL) were as follows (+ denotes increase): GIT weight, +71.5%; SI weight, +84.8%; tissue fraction of SI mucosa, +16.0%; index of quantity of mucosa per SI circumsection, +64.7%; estimate of the mass of mucosa in the whole SI organ, +108%. Although the composition of circumsections from duodenum, jejunum, and ileum differed substantially and significantly, the effects of treatments were similar at each site. Of the 542-g response (LH vs HL) of the small intestine, estimates calculated from circumsection morphometry data indicate that 55 g, 11 g, and 476 g were from muscle, matrix, and mucosa, respectively. Changes in the size of the circumsection were much greater than changes in composition. The shift in the quantity of mucosa in the circumsection was about four-fold greater than would have been predicted from the tissue fraction of mucosa. The relationship between the morphometric responses and biochemical functions of the mucosa are important to understand digestive-absorptive capacities and nutrient requirements during and immediately after a major shift in food intake.

Title: Physiology of Digestion and Nutrition in Swine. (J. C. Pekas)

This paper will be a review of progress during the last 20 years in swine gastrointestinal physiology and will include recent methods and concepts pertaining to exocrine secretions, digestion, absorption, metabolism, toxicology, morphometry, endocrinology, microbiology, and appetite. Studies involving partial direct gastric alimentation demonstrated that voluntary feed intake by swine was precisely regulated when prehension, mastication, salivation, and swallowing were partially circumvented. Total gastric alimentation of excess quantities of food (120% of control ad libitum intake; superalimentation) accelerated growth to 140% of littermate controls and demonstrated that digestion and absorption were not limiting; either swine have reserve capacities for digestion and absorption or the capacities are enhanced in response to superalimentation. The relative weights of the digestive organs increased during superalimentation. Gross measurements demonstrated that digestive organ weights of swine also respond to severe fasting and realimentation by shrinkage and enlargement, respectively. Morphometry confirmed that the response of the small intestine was principally from the mucosa fraction which in turn was principally from the villi fraction.

Title: The Effect of Growth Suppression of 100 kg Swine on Carcass Yield and Merit. (J. C. Pekas)

The objectives of the study were to determine (a) if the mass of viscera could

be reduced by feed restriction of market weight swine as has been demonstrated in young swine, and (b) if visceral shrinkage was sufficient to reduce offal weight, increase dressing percentage, and improve the yield and merit of the carcass. Forty-eight crossbred pigs (23 kg body weight) were randomly assigned to eight treatment groups (6/group) and fed a corn-soybean diet as follows: 1--ad libitum to 100 kg, then slaughtered; 2, 3, 4, 5, and 6--ad libitum to 100 kg, then feed restricted to zero gain for 7, 14, 21, 28, and 42 days, respectively, before slaughter; 7--restricted feed intake to 70% of ad libitum to 100 kg, then slaughtered; 8--ad libitum to 116 kg, then progressive feed restriction until body weight was reduced to 100 kg, then slaughtered. The treatments were compared by covariance analysis; empty body weight was the dependent variable. The least-square treatment means (treatment 1 through 8, respectively) were as follows: carcass weight (kg), 80.9, 82.3, 82.3, 82.4, 82.7, 82.8, 81.8, 82.3 ( $P=.38$ ); empty offal weight (kg), 22.40, 20.96, 20.96, 20.93, 20.63, 20.55, 21.55, 20.99 ( $P=.38$ ); dressing (%), 76.6, 78.1, 78.0, 78.2, 77.8, 78.5, 76.6, 78.4 ( $P=.059$ ); carcass backfat thickness (mm), 36, 38, 40, 38, 39, 38, 41, 36 ( $P=.66$ ); total feed intake to slaughter (kg), 266.9, 291.5, 294.1, 303.6, 310.3, 321.6, 287.0, 312.4. Compared to treatment 1 (ad libitum control) the restricted treatment groups have consistently heavier carcasses, lighter offal, and greater dressing percentages. Treatment 6, restricted to near zero gain for 42 days, had the heaviest mean carcass weight, lightest mean offal weight, and greatest mean dressing percentage; each parameter was significantly different from that of treatment 1.

Title: A Nonautoradiographic Method for Estimation of Epithelial Turnover in Gastrointestinal Organs. (J. C. Pekas)

Sprague Dawley rats (49-day-old male) were injected with  $^3\text{H}$ -thymidine (0.05  $\mu\text{Ci/g}$  body weight; intraperitoneal) to label proliferating cells. Three rats were narcotized and the gastrointestinal tract removed at 4, 24, 48, 72, and 96 hours after the dose. The stomach, small intestine (divided into three equal parts; cranial (SI-1), mid (SI-2), caudal (SI-3)), cecum and colon-rectum were dissected and the total mucosa scraped. The dry matter and  $^3\text{H}$  content were determined. The concentrations (dpm  $^3\text{H/g}$  dry matter) vs hours after dosing were plotted. The profiles revealed that: a) SI-1, -2, and -3 have similar profiles but mean concentrations were  $\text{SI-1} < \text{SI-2} < \text{SI-3}$ ; b) peak concentrations were more than two-fold greater for SI than stomach, cecum, or colon-rectum; c) peak concentrations were observed at 4 hours for stomach; 24 hours for SI-3, cecum, and colon-rectum; and at 48 hours for SI-1 and SI-2; and d) the concentration dropped precipitously after 4 hours for stomach, after 72 hours for cecum and colon-rectum, and after 48 hours for SI-1, -2, and -3. Conclusions: The results confirm a method to explore epithelial turnover without histology, autoradiography, or biochemical assays to overcome the prohibitive expense of isotope and of analytical time for autoradiographic studies with large animals.

Title: Principal Gastrointestinal Variables Associated with Fasting Heat Production: Statistical Cluster Analyses. (Jerome C. Pekas, John A. Nienaber, and James E. Wray, Jr.)

The 49 variables, in a data set of 48 observations of each variable, were classified by the multivariate method of cluster analysis (SAS software; oblique principal component analysis) to describe the principal variable(s) associated with fasting heat production (FHP). FHP and allometric mass of numerous body



tissues/organs were perturbed by feed restriction to induce catabolism (C) after a period of anabolism (A). Forty-eight weanling, crossbred, castrated, male pigs were randomly assigned to four treatment groups (AI, AF, CI, CF) and to four blocks/treatment by age (12 pigs/treatment). The AI (anabolic initial) and AF (anabolic final) groups were evaluated 14 days apart during rapid growth; the CI and CF groups, also 14 days apart, during weight loss. The nine clusters developed accounted for 80% of the variation. FHP was placed in a cluster with the weights of small intestine and jejunum; the same cluster was highly correlated ( $r > 0.8$ ) with two other clusters (consisted mainly of other gastrointestinal variables) but poorly correlated ( $r < 0.1$ ) with three other clusters (consisted mainly of whole body, skin, carcass, and thoracic variables). This evidence reinforces previous suggestions that gastrointestinal organs are important, but more importantly identifies the small intestine as a principal organ involved in FHP.

Title: Testosterone and the Incidence of Boar Taint: Effects of Testosterone or Testosterone Propionate on the Incidence of Boar Taint in Implanted Barrows. (B. D. Schanbacher, J. T. Yen and W. G. Pond)

Boars, barrows and barrows implanted with testosterone or testosterone propionate via polydimethylsiloxane (Silastic) capsules were placed on test in individual pens at 10 weeks of age. Each animal was slaughtered at 110 kg and evaluated for growth rate, efficiency of feed utilization, carcass merit and the incidence of objectionable odors (boar taint). Five capsules of testosterone or testosterone propionate were used in barrows since they substantially elevated concentrations of serum testosterone, decreased serum LH and stimulated weights of the accessory sex glands. Large variations within and between litters of pigs were found for performance and carcass traits; thus, the influences of castration and testosterone replacement therapy on these traits were inconclusive. In contrast, the effects of castration and hormone treatment on the incidence of boar taint were more definitive. The incidence of boar taint was relatively high in boars, according to a consumer taste panel. This characteristic odor was appreciably lower in barrows and was not reinstated with either testosterone or testosterone propionate implants. These results suggest that testosterone is not itself responsible for boar taint and that  $5\alpha$ -androstenone, the pheromone most closely associated with boar taint, is not produced by peripheral metabolism of testosterone. Additional studies are warranted to provide insight into the regulation of testicular steroid secretion in the boar and the contribution of these steroids to boar taint and protein anabolism.

Title: Enumeration and Activity of Cellulolytic Bacteria from Gestating Swine Fed Various Levels of Dietary Fiber. (V. H. Varel and W. G. Pond)

Cellulolytic bacteria were enumerated and cellulase activity was determined over a 98-day period from fecal samples of gestating swine fed various levels and sources of fiber. The diets, each fed to 5 pigs, were a corn-soybean control, 20% corn cobs, and 40 and 96% alfalfa meal. Fecal samples were collected from all pigs on days 0, 5, 14, 21, 35, 49, 70, and 98. Overall, the most probable number of cellulolytic bacteria from pigs fed the control, 20% corn cobs, and 40 and 96% alfalfa meal was  $23.3 \times 10^8$ ,  $15.2 \times 10^8$ ,  $45.1 \times 10^8$ , and  $52.5 \times 10^8$  per g (dry weight) of fecal sample, respectively. Enumeration of cellulolytic bacteria by counting zones of clearing in roll

tubes, as compared with the most probable number procedure, accounted for only 1.1 and 17.0% of the cellulolytic bacteria, respectively, from pigs fed the control or 96% alfalfa meal diet. Cellulolytic bacteria (most probable number) on days 70 and 98 accounted for 4.1 and 10.0% of the viable count for the pigs fed the control and 96% alfalfa meal diets, respectively. The viable count was not different between pigs fed the control and 96% alfalfa meal diets. The overall mean cellulolytic activity (milligrams of glucose released from carboxymethyl cellulose per gram [dry weight] fecal sample per 30 min was 17.0, 19.9, 23.8, and 20.6, respectively, for the control, 20% corn cobs, and 40 and 96% alfalfa meal diets. The results indicate that the cellulolytic flora can be increased by prolonged feeding of high-fiber diets and may represent 10% of the culturable flora.

Title: Influence of Dietary Fiber on Digestibility and Cellulolytic Microflora of Genetically Lean, Obese and Contemporary Pigs.  
(V. H. Varel, H. G. Jung and W. G. Pond)

The digestibility of a diet containing 80% alfalfa meal was examined in four each genetically lean, obese and contemporary pigs over a 70-day period. Fecal cellulolytic bacteria were enumerated and fecal inocula from the 3 pig genotypes were used to determine 48-hr in vitro digestibilities of alfalfa meal fractions, including cellulose, hemicellulose and total cell walls, at 0, 14, 35, 49, and 70 days. Overall, the zones of clearing produced by cellulolytic bacteria were  $30.0 \times 10^8$ ,  $16.5 \times 10^8$ , and  $22.8 \times 10^8$  per g (dry weight) of fecal samples from lean, obese and contemporary pigs, suggesting a trend for a larger number of cellulolytic bacteria in lean pigs. Bacteroides sucinogenes was the predominant cellulolytic organism isolated. In vitro digestibility of alfalfa meal cellulose, hemicellulose and cell walls was greater ( $P < 0.05$ ) for all three genotypes when they were fed 80% alfalfa meal as compared to a control low fiber diet. This increased digestibility was observed within 14 days of feeding the high fiber diet and did not change with time thereafter. The volume and weight of colon contents were less ( $P < 0.05$ ) for the obese pigs than the other two genotypes, even though feed intake was equal on a percentage of body weight basis. The smaller amount of contents for obese swine suggests that either the in vivo digestibility of fiber is greater than the other genotypes, which the counts of cellulolytic bacteria and in vitro digestibilities do not support; or the rate of passage must be faster, which is currently being analyzed.

Title: Influence of Copper-Sulfate, Aureo SP250 or Clinoptilolite on Ureolytic Bacteria Found in the Pig Large Intestine. (V. H. Varel, I. M. Robinson and W. G. Pond)

One theory for the mode of action of some antibiotics in animal growth promotion is that high concentrations of ammonia in the gastrointestinal (GI) tract can increase turnover of epithelial cells and result in more energy expenditure for maintenance of the GI tract. Compounds which reduce urease activity or bind ammonia may reduce the amount of ammonia that epithelial cells are exposed to, reduce epithelial turnover, and thus, leave more energy available for body growth.

The predominant ureolytic bacteria in the pig large intestine were determined while growing pigs were fed a basal, copper sulfate, Aureo SP250 or clinop-

tilolite diet. Fecal samples were collected from 4 pigs fed each diet at 3, 9, and 14 weeks and analyzed for total colony counts and ureolytic bacteria. Fecal urease activity, ammonia nitrogen and identification of the ureolytic bacteria were also determined at 14 weeks. Copper sulfate and Aureo SP250 reduced the number of ureolytic organisms, with a marked decrease occurring in the *Streptococcus* sp., which made up 74% of the ureolytic isolates. *Staphylococcus* sp., *Selenomonas ruminantium*, *Bacteroides multiacidus* and *Eubacterium limosum* were other ureolytic species detected. Copper sulfate also reduced fecal urease activity. Fecal ammonia concentrations or pig weight gain were not different between diets. These data suggest that the streptococci are one of the most numerous ureolytic species in the pig intestinal tract and are significantly reduced by copper sulfate and Aureo SP250; however, only copper sulfate reduced intestinal urease activity.

Title: Plasma Thyroid Hormones, Growth and Carcass Measurements of Genetically Obese and Lean Pigs as Influenced by Thyroprotein Supplementation. (J. T. Yen and W. G. Pond)

A 2 x 2 factorial arrangement with two genotypes of pigs (genetically obese and lean) and two dietary treatments (basal, a 16% protein corn-soybean meal standard grower diet, and basal + 220 ppm thyroprotein as iodinated casein) was used. The 28 gilts were housed individually and fed ad libitum from 121 days of age until slaughtered at 99 kg body weight. Compared with lean pigs, genetically obese pigs had significantly lower average daily gain and gain/feed, greater backfat thickness, smaller loin eye area, shorter carcass length, and lower circulating plasma triiodothyronine ( $T_3$ ) concentration. However, both total plasma and free thyroxine ( $T_4$ ) concentrations were similar comparing obese and lean pigs. Supplementation with thyroprotein increased circulating plasma concentration of both total and free  $T_4$  and produced interactions with genotype in affecting daily gain and gain/feed of pigs. Thyroprotein reduced both daily gain and gain/feed in obese pigs, but increased daily gain and gain/feed in lean pigs. It is suggested, similar to the case with obese mice, that heat production of our genetically obese pigs may be more sensitive to thyroprotein administration compared with similar treatment of lean animals.

Title: Effect of Carbadox on Growth, Fasting Metabolism, Thyroid Function and Gastrointestinal Tract in Young Pigs. (J. T. Yen, J. A. Nienaber, W. G. Pond, and V. H. Varel)

Five experiments were done with 34 weanling and 24 growing crossbred gilts. Individually penned pigs were fed ad libitum (Expt. 1) or pair-fed (Expt. 2 through Expt. 5) for either 2 (Expt. 1 through Expt. 4) or 3 (Expt. 5) weeks. Mean body weight gain and gain/feed values were significantly ( $P < 0.05$ ) greater in pigs fed carbadox (a synthetic antimicrobial). Fasting  $O_2$  consumption and  $CO_2$  production of pigs were measured during the 32- to 48-hour (Expt. 1, 4 and 5) or during the 24- to 40-hour (Expt. 2 and 3) postprandial periods with indirect open circuit calorimeters. Carbadox reduced  $O_2$  consumption significantly ( $P < 0.05$ ) in Expt. 2, but had no significant effect on  $CO_2$  production in any of the 5 experiments. The weight of thyroid gland and the plasma concentrations of L-3,3',5-triiodothyronine ( $T_3$ ) and thyroxine ( $T_4$ ) of pigs were not altered by carbadox. The mean weight, but not the length, of small intestine tended to be less in pigs fed carbadox. It is suggested that the



growth-promoting effect of carbadox on young pigs may be associated with the weight of small intestine and its physiological processes such as metabolic rate. However, no definite effects of carbadox on whole-animal fasting metabolic rate and thyroid function could be demonstrated by the methods used in the present study.

Title: A Method for Quantifying Absorption of Nutrients and Metabolites in Conscious Swine. (J. T. Yen and J. Killefer)

Surgical technique was developed for chronic cannulation of portal vein, ileal vein and abdominal aorta in pigs weighing 20 to 40 kg. Silastic tubing with 1.02 mm I.D., 2.16 mm O.D. and .76 mm I.D., 1.65 mm O.D. were used for cannulating portal vein and ileal vein, respectively. The abdominal aorta was cannulated via saphenous artery with vinyl tubing (.71 mm I.D., 1.17 mm O.D.) pretreated with TDMAC-heparin complex. The procedure allowed for the simultaneous collection of blood from the portal vein and abdominal aorta and the continuous infusion of p-aminohippuric acid (PAH) into the ileal vein. The constant PAH infusion provided an indicator-dilution method for estimating the blood flow rate in the portal vein. By simultaneously measuring the concentration of nutrients and metabolites in the portal and aortic blood and multiplying porto-arterial differences by the estimated portal blood flow rate, the absorption of nutrients and metabolites in conscious swine can be quantified.

Title: Portal Vein Blood Flow Rate and Net Portal Absorption Of Glucose, Ammonia and Blood Urea Nitrogen in Conscious Swine. (J.T. Yen and J. Killefer)

Chronic cannulas were placed into the portal vein, ileal vein and abdominal aorta of gilts weighing 30 to 40 kg, initially, to determine portal vein blood flow (PVBF) and net absorption of glucose (GLU), ammonia (NH<sub>3</sub>) and blood urea nitrogen (BUN) into portal vein in conscious swine. Pigs were fed once daily at 8:30 a.m. Simultaneous measurements of PVBF and porto-arterial (P-A) concentration differences in GLU, NH<sub>3</sub> and BUN were made every 30 minutes during .5 hour pre- to 4 hour postprandial period and then hourly during 4 to 8 hours postprandial period. By employing a continuous infusion indicator-dilution technique (p-aminohippuric acid used as the indicator, infused into ileal vein), the PVBF was estimated to be  $1,396 \pm 41$  ml/minute on the basis of 293 determinations obtained from six gilts. The net absorption into the portal vein was estimated by multiplying P-A differences by PVBF and was found to be  $379 \pm 17$  mg/minute for GLU,  $3.601 \pm .160$  mg/minute for NH<sub>3</sub> and  $7.15 \pm .62$  mg/minute for BUN in those gilts.

Title: Performance, Fasting Metabolism and Gastrointestinal Tract of Young Pigs Fed Carbadox or Neomycin. (J. T. Yen, J. A. Nienaber and W. G. Pond)

Five sets of littermate trio gilts (8.2 kg avg initial wt) were randomly assigned within litter to a basal (16% protein corn-soybean meal) diet (B), B + .308% neomycin (N), or B + 55 ppm carbadox (C). Pigs were pair-fed individually once daily for 15 days in metabolism cages and 6 days in calorimeters. The average daily feed intake for 21 days was 276 g. Oxygen consumption (O<sub>2</sub>) and CO<sub>2</sub> production (CO<sub>2</sub>) were measured during an 8- to 24-hour postprandial

period on day 16, 19, 20, and 21, and during a 32- to 48-hour postprandial period after day 21 feeding. Pigs were killed 50 hours postprandially for gastrointestinal tract measurements. Some results of the study are summarized as follows:

Item	Diet: B N C				Statistical significance	
				SE	P<.05	
Avg daily gain, g	86	124	120	4	B vs (N+C)	
Gain/feed	.31	.45	.42	.02	B vs (N+C)	
Small intestine wt/body wt, %	3.69	3.24	3.33	.12	B vs (N+C)	
32-48 h fasting O <sub>2</sub> , liter/(h·kg. <sup>.75</sup> )	.99	.98	.91	.03	NS	
32-48 h fasting CO <sub>2</sub> , liter/(h·kg. <sup>.75</sup> )	.84	.84	.79	.03	NS	

The results also showed no differences ( $P>.05$ ) in 8-24 hour fasting O<sub>2</sub> and CO<sub>2</sub> measurements determined on day 16, 19, 20, or 21, and indicated that no adaptation to calorimeters was needed by our pigs. The present study, thus, confirms our hypothesis that the growth-promoting effect of certain antimicrobial agents (e.g., carbadox, neomycin) on young pigs is related to the weight and its associated metabolic processes of small intestine and that this effect cannot be detected consistently by measuring whole-animal fasting metabolic rate.

Title: Blood Flow and Steroid and Nutrient Uptake of the Gravid Uterus and Fetus of Sows. (L. P. Reynolds, S. P. Ford and C. L. Ferrell)

Uterine and umbilical blood samples and blood flow (BF) measurements were obtained from one uterine horn and a single fetus of sows at day 70, 90 and 110 of gestation. Concentrations of O<sub>2</sub> in blood and of estrogen (E), progesterone (P), glucose,  $\alpha$ -amino nitrogen (N), and urea N in plasma were determined. Fetal weights were  $.267 \pm .018$ ,  $.633 \pm .019$  and  $1.208 \pm .073$  kg on day 70, 90 and 110, respectively. Uterine and umbilical BF remained constant with day of gestation, averaging  $1.51 \pm .06$  and  $.31 \pm .02$  liters/min. Uptake of P by a uterine horn and fetus remained constant, but secretion of E by a uterine horn and uptake of E by a fetus increased ( $P<.05$ ) with stage of gestation. Uterine and fetal uptake of O<sub>2</sub>, glucose and  $\alpha$ -amino N did not change and uptake of O<sub>2</sub>, glucose and  $\alpha$ -amino N per kg fetus decreased ( $P<.01$ ) as gestation advanced. Secretion of urea N from the uterus was observed, with a concentration gradient from the fetal to the uterine circulations. Uterine and fetal respiratory quotients for glucose were .79 and .38, respectively. Thus, although glucose potentially served as a major energy source, a large portion of the energy requirements of the fetal pig were met by catabolism of other substrates. The decrease in umbilical BF and uptake of nutrients per kg fetus with day of gestation suggested that porcine fetal metabolism declined as pregnancy advanced.

Title: Influence of Plane of Nutrition on Body Composition, Organ Size and Energy Utilization of Sprague-Dawley Rats. (C. L. Ferrell and L. J. Koong)

Male (61) and female (54) Sprague-Dawley rats (31 days of age, 85 g) were used to evaluate the influence of plane of nutrition on body composition, internal organ size and energy utilization. Six male and nine female rats were sacri-



ficed initially. The remaining animals were randomly assigned, within sex, and fed to gain either 105 gm (H) or 40 gm (M) or lose 25 gm (L) during a 21-day period. Nine rats each from the H and M groups and six from the L group were then sacrificed. The remaining rats from the H (27) and M (27) groups were fed to gain at the H, M or L rates and rats from the L (12) groups were fed to gain at the H or M levels during a second 21-day period. All rats were sacrificed at the end of the second period. Body composition and weights of internal organs were determined and relationships between energy intake and energy gain were evaluated. Results indicated that at the end of period 2, body composition at equal age and body weight was influenced by nutritional treatment. At equal body weight, body protein weights were lower ( $P < 0.05$ ) and body fat, liver and gut weights were higher ( $P < 0.05$ ) for rats on higher planes of nutrition. Feed required for maintenance of rats during period 2 tended to be lower and efficiencies of gain tended to be higher for rats fed the low level than for those fed the high level during period 1. Rats fed the medium level during period 1 had similar maintenance requirements but higher efficiencies of gain during period 2 than rats fed the high level during period 1. These data suggest previous nutrition influenced energy utilization through adaptation of high energy expending internal organs as well as through alterations in body composition of gain.

Title: Visceral Organ Mass and Hepatic Protein Synthetic Capacity in Fed and Fasted Rats. (D. B. Burrin, R. A. Britton and C. L. Ferrell)

Forty-two male rats (avg wt = 320 g) were used to assess the effect of severe nutrient restriction (72 hour fast) on visceral organ mass and hepatic protein synthetic capacity as measured by in vitro incorporation of U- $^{14}$ C-Valine ( $^{14}$ C-Val) into isolated hepatocytes. Organ weights expressed as a percent of empty body weight fed vs fasted rats were: liver ( $5.21 \pm .54$  vs  $3.82 \pm .46$ ), kidney ( $.87 \pm .06$  vs  $.89 \pm .05$ ), stomach ( $.60 \pm .06$  vs  $.61 \pm .06$ ), intestines ( $3.70 \pm .44$  vs  $3.41 \pm .37$ ). No differences were observed in in vitro oxygen consumption ( $15.7 \pm 3.1$  vs  $16.1 \pm 3.3$ ,  $\mu\text{mole min}^{-1}\text{g}^{-1}$  dry tissue) or  $^{14}$ -C Val incorporation ( $4.93 \pm 1.29$  vs  $4.31 \pm 1.48$ ,  $\text{dpm min}^{-1}\text{mg}^{-1}$  dry tissue) for hepatocytes from fed vs fasted rats. Analysis of perfused liver tissue indicated fed rats had higher protein ( $152.1 \pm 16.3$  vs  $136.6 \pm 29.6$ ,  $\text{mg/g tissue}$ ) and RNA ( $8.81 \pm 1.66$  vs  $5.97 \pm 1.87$ ,  $\text{mg/g tissue}$ ) with lower DNA ( $2.19 \pm .32$  vs  $3.19 \pm .54$   $\text{mg/g tissue}$ ) compared to fasted rats. Protein-nucleic acid ratios suggest liver tissue from fed rats had a greater capacity for protein synthesis compared to fasted rats, however, this was not evident from in vitro hepatocyte  $^{14}$ -C Val incorporation estimates. These data indicate that severe nutrient restriction (74 hour fast) affects visceral organ mass largely by reduced liver and gut size as well as decreased hepatic protein synthetic capacity.

Title: Response of the Liver of Suckling-Age Pigs to Short-Term Maternal Deprivation. (W. G. Pond, L. H. Yen, H. G. Klemcke, and J. T. Yen)

Ornithine decarboxylase (ODC) is involved in regulation of protein and nucleic acid synthesis. Brief separation of rat pups from the dam abruptly reduces liver ODC activity (PSEBM 175:135, 1984). This experiment was done to monitor liver ODC in suckling piglets following short-term separation from their dams. Two female pigs from each of 23 litters (5, 5, 4, 5, and 4 litters at days 3, 10, 17, 24, and 31 days of age), were used. C (control) pigs remained with

dam while F (fasted) pigs were placed with a nonexperimental littermate in a box near dam and littermates for 16 hr before slaughter. Data on prefasting body wt (BW), liver wt (L), plasma glucose (G), and liver ODC are summarized below.

n	Age, d	BW, kg			L, % BW			G, mg/dl			ODC, dpm/300 mg		
		C	F	SD	C	F	SD	C	F	SD	C	F	SD
10	3	1.49	1.42	.19	.35	.26**	.04	132	96**	14	505	160**	151
10	10	3.28	2.94	.48	.30	.22**	.02	144	127	24	767	299	344
8	17	4.49	4.18	.89	.29	.21*	.04	148	112	22	401	230	- <sup>a</sup>
10	24	6.55	6.05	1.45	.23	.20	.02	116	98**	8	368	163**	105
8	31	7.87	7.93	.95	.25	.21	.02	109	100	10	216	123*	57
Overall		4.61	4.37	3.07	.28	.22**	.05	130	107**	20	458	100**	232

<sup>a</sup> Only one pair analyzed. \* F<C (P<.05); \*\* F<C (P<.01).

We conclude that liver ODC activity is markedly reduced by 16 hr of maternal deprivation in suckling-age pigs; it is suggested that ODC activity may be a useful correlate of indices of growth and development in swine.

Title: Effects of Restricted Feed, Nonprotein Calories or Protein in Swine Gestation. (W. G. Pond and J. T. Yen)

Objective was to determine effect of severe restriction of feed, nonprotein calories or protein during pregnancy on dam body wt, backfat and reproduction, and on progeny growth in swine. Primiparous gilts were assigned to diets at breeding as follows: 1) Control (C, 1.8 kg, 6000 kcal DE/d to term), 2) "Protein-free" (PF, 1.8 kg, 6000 kcal DE/d to term), 3) Restricted control (R, 2000 kcal DE/d to d 70, then 1.8 kg/d C to term), 4) Restricted nonprotein calories (RCal, 2000 kcal DE/d to 70 d, then 1.8 kg/d C to term). RCal diet had 3 x concentrations of all ingredients but carbohydrates compared with C diet. All gilts were fed standard diet ad lib through 4-wk lactation. Results for selected traits are as follows:

	Diet: C		PF	R	RCal	SD	Prob.
No. litters	7		5	6	5		
Litter size	11.1		8.4	10.8	8.8	2.5	NS
Dam wt gain 0-70 d, kg	28.0 <sup>a</sup>		-3.1 <sup>b</sup>	3.9 <sup>b</sup>	-1.0 <sup>b</sup>	5.6	<.01
Dam wt gain, 71-110 d, kg	10.1 <sup>a</sup>		-8.4 <sup>b</sup>	20.7 <sup>c</sup>	7.1 <sup>a</sup>	8.3	<.01
Individual birth wt, g	1350 <sup>a</sup>		990 <sup>b</sup>	1188 <sup>a</sup>	1218 <sup>a</sup>	230	<.10
Number weaned/litter	7.4		6.6	7.8	7.2	1.2	NS
Litter wt, 4-wk, kg	52.6 <sup>a</sup>		33.4 <sup>b</sup>	48.0 <sup>a</sup>	51.7 <sup>a</sup>	9.2	<.01

abc Means in same row without a common superscript differ.

The PF diet more severely affects progeny birth wt and preweaning wt gain than R or RCal. Nutrients other than calories do not appear to limit reproduction in dams restricted during the first two-thirds of pregnancy to one-third of feed recommended by NRC.

Title: Response of Sow and Fetus Organ Weights to Gestation Feed Restriction.  
(W. G. Pond, J. T. Yen and L. H. Yen)

Crossbred primiparous and paired unmated gilts were assigned at time of mating to adequate (A; 1.8 kg/day) or restricted (R; 0.6 kg/day) feed intake. On day 84 all gilts were slaughtered (8 pregnant (P) and 8 nonpregnant (NP) fed A and 9 P and 9 NP fed R), reproductive tract (RT), empty gastrointestinal tract (GIT), liver, kidneys, and leaf fat (LF) were weighed. Uteri of P gilts were opened, fetus removed and fetal body, liver, GIT, pancreas, and brain cortex were weighed. Umbilical artery blood was sampled from fetuses in each litter for plasma glucose. Means for selected traits are in the table.

Trait	Adequate feed (A)		Restricted feed (R)		SD	Prob.
	P	NP	P	NP		
11 wk body wt, kg	140.1	131.8	107.5	99.8	7.3	<.01
GIT, g	3190	3378	2326	2292	101	<.01
RT, g	3282	745	3632	442	391	<.01
LF, g	982	1430	443	447	338	<.01
No. fetuses/litter	8.75		9.44		3.0	NS
Fetus wt, kg	474		414		59	<.05
Brain wt, % body wt	2.60		3.06		.33	<.05

Pregnant gilts fed R had greater RT but lower LF weight than those fed A; P and NP gilts fed R had similar LF weights. Pregnancy had no effect on GIT weight. Individual fetal weight was less and relative weight of brain was greater in progeny of R dams. Relative weights of liver, GIT and kidney and concentration of plasma glucose in fetuses were not affected by maternal diet.

Title: Plasma Growth Hormone in Pregnant Gilts and Their Fetuses.  
(W. G. Pond, L. H. Yen and J. T. Yen)

Thirty-four crossbred primiparous gilts fed a standard gestation diet at 6000 or 2000 kcal DE (1.8 or 0.6 kg feed) daily were fitted with an indwelling jugular cannula to allow frequent blood sampling at day 77 or 100 of pregnancy. Blood was collected from eight gilts in each group 33 times over an 8-hour period for plasma growth hormone (GH) and glucose assay. Fetuses were removed from each gilt at day 84 or 108 of pregnancy and GH and glucose concentrations were measured in plasma from umbilical arterial blood. Fetal body weight at 84 and 108 days was reduced by about 13% in restricted (R) gilts compared with adequately fed (A) gilts (407 vs 472 g at 84 days and 911 vs 1040 g at 108 days, respectively;  $P < .04$ ). Maternal plasma glucose was unchanged by restricted feed (94.0 vs 94.9 mg/dl in R vs A gilts, respectively), while plasma growth hormone peak amplitude (35.3 vs 13.6 ng/ml, respectively), but not mean concentration or number of peaks, was increased by feed restriction. Mean GH concentration was 32.3 vs 26.3 ng/ml (nonsignificant) and number of peaks/8 hours was 1.63 vs 0.75 (nonsignificant), respectively, for R and A gilts. Fetal plasma glucose was higher (190 vs 41 mg/dl,  $P < .01$ ) and plasma GH lower (163 vs 293 ng/ml,  $P < .01$ ) at 108 days than at 84 days. Maternal diet did not affect fetal plasma GH or glucose. Fetal plasma GH was negatively correlated with fetal body weight ( $r = -.802$ ,  $P < .01$ ) and with fetal plasma glucose ( $r = -.404$ ,  $P < .05$ ). It is concluded that the extent of fetal growth retardation associated with maternal feed restriction is similar at 84 days to that at 108 days and that the observed increase in peak amplitude of GH concentration in maternal plasma in R gilts is a metabolic adaptation which may be related in some way to fetal growth in swine.

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## Sheep

Title: Changes in Concentrations of Rumen and Blood Constituents in Ewes During Adaptation to Dietary Urea With and Without Supplemental Clinoptilolite. (Wilson G. Pond and Lei H. Yen)

Seven rumen-fistulated mature crossbred (Rambouillet x Finnsheep) ewes were individually fed for 5 days a complete high concentrate corn-soybean meal-alfalfa diet ad libitum (2 ewes) or the same basal diet (B) diluted with 1.0% urea (BU; 3 ewes) or 1.0% urea plus 2.0% clinoptilolite (BUC; 2 ewes). A jugular blood sample and a rumen fluid sample were obtained from each ewe at 9 a.m. and 3 p.m. 2 days before assignment to diets and daily for 5 days after introduction to the diets. Feed consumed by ewes fed BU was less than that of ewes fed B or BUC. Hematocrit and hemoglobin were higher in ewes fed BU or BUC than in those fed B, indicating shifts in fluid movement in and out of the cardiovascular compartment. Rumen pH was increased in BU and BUC ewes compared with B ewes. Plasma Ca was reduced by BU, but not by BUC, compared with B diet. Plasma inorganic P was reduced by BU and the reduction appeared more severe with BUC. Plasma K concentration was reduced by BU and was further reduced at the a.m. sampling periods by the BUC diet, compared with B diet. It is concluded that adaptation of ruminants to urea feeding is associated with adjustments in movement of fluids and electrolytes among body compartments and between blood and rumen lumen. Clinoptilolite, whose ammonia- and cation-binding properties appear operative at physiological pH, modulates the response of the rumen and host animal to urea during early dietary adaptation. The full significance of and the possible avenues for exploiting these properties of clinoptilolite need to be explored.

Title: Effect of Dietary Protein and Clinoptilolite Levels on Weight Gain, Feed Utilization and Carcass Measurements in Finishing Lambs. (Wilson G. Pond)

Sixty-four intact male lambs (24 Dorsets and 40 crossbreds representing advanced generations of a composite population of 50% Finnish Landrace (FL), 25% Dorset (D) and 25% Rambouillet (R) breeding) were fed ad libitum individually for 42 days in a 2 x 4 factorial arrangement of diet treatments (10 or 15% protein and 0, 1, 2, or 4% clinoptilolite). Body weight gain, feed consumption and gain/feed were recorded for 42 days and carcass measurements were taken on all lambs at slaughter. Lambs fed 15% protein tended to gain more body weight ( $P < .07$ ) than those fed 10% protein, converted feed to body weight gain more efficiently ( $P < .02$ ) and had a higher ( $P < .03$ ) leg conformation score. The addition of 2 or 4% clinoptilolite to the diet was associated with greater body weight gain ( $P < .01$ ) and gain/feed ( $P < .01$ ) than a level of 1%; weight gain and gain/feed of lambs fed diets containing 1% clinoptilolite were not significantly different from those not fed clinoptilolite. Crossbred (FL x D x R) lambs had greater body weight gain ( $P < .01$ ), gain/feed ( $P < .01$ ), percentage of kidney fat ( $P < .01$ ) and leg conformation score ( $P < .01$ ) than Dorset lambs. There were no interactions between diet and breed or between dietary protein level and clinoptilolite level for any trait measured. The data provide no evidence for breed differences in response to low dietary protein, but suggest that a supplemental level of 2% clinoptilolite ( $\text{NH}_4^+$  binding capacity of 1.58 meq/g) improves weight gain and gain/feed in intact male lambs fed high concentrate diets during the finishing period.



Title: Weight Gain and Digestive Tract Development at 42 Days in Lambs  
Weaned to a Dry Diet at 10, 14, or 28 Days of Age.  
(Wilson G. Pond and Mike H. Wallace)

Thirty-two Finnish Landrace lambs removed from their dams at one day of age were assigned randomly at three days of age to four treatment groups. Lambs were penned individually in .3 x 1.2 m wire-bottom cages and were weaned from liquid milk replacer to a dry modified pig starter diet at 10, 14 or 28 days of age. Half of the lambs weaned at 10 days of age received tap water (500 ml) twice daily from a nursing bottle; all lambs had free access to tap water flowing continuously through a plastic trough attached to all pens. Body weight and dry and liquid feed consumption of each lamb were recorded at 0, 10, 28 and 42 days. Sixteen lambs (4/treatment group) were used to monitor blood hemoglobin, hematocrit and plasma total protein, albumin, urea-N, glucose and acetate weekly throughout the 42 day experiment. At slaughter, the gastrointestinal tract, kidney and liver were removed from each lamb; pH of rumen, abomasum and colon and full and empty weights of rumen-reticulum, abomasum, cecum and small intestine were recorded and samples of rumen and cecum contents were saved for determination of volatile fatty acid concentrations. Daily weight gain to 28 days was greater in lambs weaned to dry diet at 28 days (DD28) than in other lambs ( $P < .01$ ), but from 28 to 42 days the reverse was true ( $P < .01$ ). Overall daily gain (0 to 42 days) was greater in DD28 lambs than in lambs weaned at 10 or 14 days ( $P < .01$ ). Gain/feed was unaffected by treatment during the periods 10 to 28 days and 29 to 42 days, but was greater from 0 to 42 days for DD28 lambs than for those weaned earlier. Hemoglobin, hematocrit ( $P < .01$ ) and plasma glucose ( $P < .05$ ) were higher and plasma urea-N was lower ( $P < .01$ ) in DD28 lambs than in other lambs. There was no effect of treatment on plasma total protein, albumin or acetate. Full and empty weights of rumen-reticulum, abomasum and cecum and concentrations of volatile fatty acids in rumen and cecum at 42 days were unaffected by treatment. It is concluded that the lamb weaned to a dry diet at 10 to 14 days of age is a fully functioning ruminant by day 42 and that weaning at 10 days is associated with survival and growth at least equal to values obtained when weaning is at 14 days. Weight gain to 42 days may be increased by weaning at 28 days rather than at 10 or 14 days.

Title: Environmental Effects on Gain and Response to Epinephrine Challenge in Lambs. (J. Eisemann, L. Hahn, B. Schanbacher, and J. Nienaber)

Plasma glucose (GLU) and nonesterified fatty acid (NEFA) responses to an IV challenge with L-epinephrine bitartrate (EPI;  $2 \mu\text{g}$  base/kg BW) were evaluated in 24 crossbred ram lambs ( $55.6 \pm 1.2$  kg) that had been fasted for 24 hours following alteration in environmental light:dark regimen (L:D) or temperature for 9 weeks. The three treatments (8 lambs each) were: 8L:16D,  $10^\circ\text{C}$  (C); 7L:8D:1L:7D,  $10^\circ\text{C}$  (L); and 8L:16D,  $-10^\circ\text{C}$  (T). Means are presented below for C, L, and T groups, respectively. Average daily gains (g/d) were greater ( $P < .05$ ) in L than T lambs. Means (SE) were: 360, 380, 335 (14). Basal and peak GLU (mg/dl) were higher ( $P < .05$ ) in L and T than in C lambs; however, total area under the response curve ( $\text{mg} \cdot \text{dl}^{-1} \cdot \text{min}^{-1}$ ) from 0-90 min postinjection (PI) did not differ among groups. Means (SE) were: basal GLU 83.0, 89.8, 86.9 (2.2); peak GLU 116.3, 125.6, 125.4 (3.1); and GLU area 1386.4, 1472.9, 1753.1 (149.8). Basal NEFA ( $\mu\text{Eq/L}$ ) were not different among groups; however, peak NEFA ( $\mu\text{Eq/L}$ ) and total response area ( $\text{mEq} \cdot \text{L}^{-1} \cdot \text{min}^{-1}$ ), from 0-60

min PI were lower ( $P < .05$ ) in L and T than in C lambs. Means (SE) were: basal NEFA 570, 578, 559 (53); peak NEFA 1063, 858, 743 (59); and NEFA area 18.01, 7.00, 4.68 (4.52). Environment altered metabolic response; however, these data do not support a change in tissue sensitivity to EPI as part of the metabolic adjustments responsible for increased gain in L vs T lambs.

Title: Effect of Growth Rate and Compensatory Growth on Body Composition in Lambs. (O. A. Turgeon, Jr., D. R. Brink, S. J. Bartle, T. J. Klopfenstein, and C. L. Ferrell)

Fifty lambs were used in a comparative slaughter experiment to determine the effects of growth rates on body composition and the subsequent changes in body composition during compensatory growth. The study consisted of a growing and at finishing phase. During the growing phase (20-30 kg) lambs were fed to gain at three different rates (Slow, Medium and Rapid). The finishing phase consisted of two periods (Early, 30-38 kg; Late, 38-45 kg). All lambs received 70% concentrate diets during the finishing phase. Groups of five lambs were sacrificed at 20, 30, 38, and 45 kg fleece-free liveweights for whole body chemical analysis. At 30 kg, the rapidly grown lambs were the fat-test ( $P < .01$ ) and contained less protein ( $P < .05$ ) in their empty bodies. The slower lambs gained during the growing phase the greater ( $P < .05$ ) was the response in rate of gain and feed efficiency during both periods of the finishing phase. Compensatory growth occurred in two stages: (1) Early, increased rate of protein growth, and (2) Late, increased rate of fat growth. Consequently, a greater proportion of the protein gain was made early while a greater proportion of the fat gain was made during the late period of the finishing phase.

Title: Effect of Previous Nutrition on Body Composition and Maintenance Energy Costs of Growing Lambs. (C. L. Ferrell, L. J. Koong and J. A. Nienaber)

The phenomenon of compensatory gain, in which a faster or more efficient rate of gain, or both has been observed following a period of nutritional or environmental stress, has been studied for a number of years. Webster, in 1979, reviewed some of the current literature and concluded that the compensatory gain response was primarily a result of differences in the composition of body tissue gained during the period of realimentation. Information available in this area, however, is not consistent. Information is available, for example to show that at similar body-weights, body fat is increased, not changed or decreased, after a period of realimentation. Several reports have shown that fasting heat production (FHP) or maintenance requirements decrease in response to low levels of feed intake. Other reports indicate FHP or maintenance was not influenced by nutritional level. In many of these studies, however, the influences of nutritional level, duration of nutritional treatment, age or body weight, or both, have been confounded.

Therefore, the objectives of the present study were to evaluate the influence of nutritional manipulation on body composition of lambs at the same age and weight and to ascertain the effects of previous nutritional manipulation on food utilization by lambs.

Forty-eight intact male lambs (30 kg) were fed to gain 16 (H), 5 (M) or -6 (L) kg during a 42-day interval (period 1). Lambs from each of the H and M groups

were fed to gain either 16 (HH, MH), 5 (HM, MM), or -6 (HL, ML) kg and lambs from the L groups were fed to gain 27 (LS), 16 (LH) or 5 (LM) kg during the ensuing 42-day (period 2). Fasting heat production (FHP) of four lambs of each treatment was determined at the end of period 2. Weights and compositions of the carcass, offal and digesta free body as well as weights of major internal organs were determined for four lambs of each treatment at the end of periods 1 and 2. Within groups of lambs of similar weight at the end of period 2, body composition was, in general, similar, but FHP was greater in lambs that had been on higher planes of nutrition during period 2. Within groups of lambs of similar weight, lambs that were fed at higher planes of nutrition during period 2 had greater weights or proportions of liver, small intestine, large intestine, and stomach. Neither weight of the liver, kidney, stomach, small intestine, large intestine, nor daily fasting production were constant functions of body weight. Relationships of these traits to body weight changed with rate of gain. Regression analysis indicated the feeding of lambs at higher planes of nutrition during period 1 resulted in higher maintenance requirements of those lambs during period 2.

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